

A MULTIMETRIC BENTHIC INDEX FOR GEORGIA'S WADEABLE STREAMS

Amanda Lynn Middleton



Digitized by the Internet Archive
in 2012 with funding from
LYRASIS Members and Sloan Foundation

<http://archive.org/details/multimetricbenth00midd>

Columbus State University
College of Science
The Graduate Program in Environmental Science

A Multimetric Benthic Index for Georgia's Wadeable Streams

A Thesis in
Environmental Science

By
Amanda Lynn Middleton

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Master of Science

June 2006

© 2006 by Amanda Lynn Middleton



I have submitted this thesis in partial fulfillment of the requirements for the degree of Master of Science.

17 July 2006
Date

Amanda L. Middleton
Amanda Lynn Middleton

We approve the thesis of Amanda Lynn Middleton as presented here.

25 JULY 2006
Date

James A. Gore
James A. Gore, Department Chair of
Environmental Science Policy &
Geography

26 July 2006
Date

George Stanton
George Stanton, Professor of Biology

26 July 2006
Date

Julie Ballenger
Julie Ballenger, Professor of Biology

I have submitted this thesis in partial fulfillment of the requirements for the
degree of Master of Science

Date

Date

Date

Date

TABLE OF CONTENTS

List of Figures	iv
List of Tables.....	x
Abstract.....	xvii
Introduction	1
Methods	9
Results	14
Discussion.....	140
Appendix A.....	152
Appendix B.....	173
Appendix C	198
Appendix D	208
Appendix E.....	216
Appendix F	218



LIST OF FIGURES

Figure	Page
1 Level III & Level IV Ecoregions of Georgia.....	16
2 Georgia Ecoregions Reference Sites Sampled	17
3 Georgia Ecoregions Impaired Sites Sampled.....	18
4 Ecoregion 45 – Piedmont.....	20
5 Discriminating Index Characteristic between Reference and Impaired Streams for Ecoregion 45	21
6 45a – Southern Inner Piedmont	26
7 Typical Reference Stream – Subcoregion 45a.....	26
8 Typical Impaired Stream –Subcoregion 45a	27
9 Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 45a.....	28
10 45b – Southern Outer Piedmont	29
11 Typical Reference Stream – Subcoregion 45b	30
12 Typical Impaired Stream – Subcoregion 45b	30
13 Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 45b.....	31
14 45c – Carolina Slate Belt	33
15 Typical Reference Stream – Subcoregion 45c.....	33
16 Typical Impaired Stream – Subcoregion 45c	34
17 Discrimination Index Characteristic between Reference and Impaired Streams for Subcoregion 45c.....	36
18 45d – Talladega Upland.....	37
19 Typical Reference Stream Subcoregion 45d	38



20	Typical Impaired Stream – Subcoregion 45d	38
21	Discrimination Index Characteristic between Reference and Impaired Streams for Subcoregion 45d.....	39
22	Subcoregion 45h – Pine Mountain Ridges.....	41
23	Typical Reference Stream – Subcoregion 45h	41
24	Typical Impaired Stream – Subcoregion 45h	42
25	Discrimination Index Characteristic between Reference and Impaired Streams for Subcoregion 45h.....	43
26	Ecoregion 65 – Southeastern Plains.....	45
27	Discrimination Index Characteristic between Reference and Impaired Streams for Ecoregion 65	46
28	65c – Sand Hills	52
29	Typical Reference Stream – Subcoregion 65c.....	52
30	Typical Impaired Stream – Subcoregion 65c	53
31	Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 65c.....	54
32	65d – Southern Hilly Gulf Coastal Plain	55
33	Typical Reference Stream – Subcoregion 65d	56
34	Typical Impaired Stream – Subcoregion 65d	56
35	Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 65d.....	58
36	65g – Dougherty Plain	59
37	Typical Reference Stream – Subcoregion 65g	60
38	Typical Impaired Stream – Subcoregion 65g	60



39	Discriminating Index Characteristic between Reference and Impaired Streams for Subecoregion 65g.....	61
40	65h – Tifton Upland.....	63
41	Typical Reference Stream – Subecoregion 65h	63
42	Typical Impaired Stream – Subecoregion 65h	64
43	Discriminating Index Characteristic between Reference and Impaired Streams for Subecoregion 65h.....	66
44	65k Coastal Plain Red Uplands	67
45	Typical Reference Stream – Subecoregion 65k.....	68
46	Typical Impaired Stream – Subecoregion 65k	68
47	Discriminating Index Characteristic between Reference and Impaired Streams for Subecoregion 65k.....	70
48	65l – Atlantic Southern Loam Plains (Vidalia Uplands).....	71
49	Typical Reference Stream – Subecoregion 65l.....	72
50	Typical Impaired Stream – Subecoregion 65l	72
51	Discriminating Index Characteristic between Reference and Impaired Streams for Subecoregion 65l.....	74
52	65o – Tallahassee Hills/Valdosta Limesink.....	76
53	Typical Reference Stream – Subecoregion 65o	76
54	Typical Impaired Stream – Subecoregion 65o	77
55	Discriminating Index Characteristic between Reference and Impaired Streams for Subecoregion 65o.....	78
56	Ecoregion 66 – Blue Ridge	80
57	Discriminating Index Characteristic between Reference and Impaired Streams for Ecoregion 66	81
58	66d - Southern Crystalline Ridges & Mountains.....	85



59	Typical Reference Stream – Subcoregion 66d.....	85
60	Typical Impaired Stream – Subcoregion 66d	86
61	Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 66d.....	87
62	66g – Southern Metasedimentary Mountains.....	88
63	Typical Reference Stream – Subcoregion 66g.....	89
64	Typical Impaired Stream – Subcoregion 66g	89
65	Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 66g.....	90
66	66j-Broad Basins.....	92
67	Typical Reference Stream – Subcoregion 66j.....	92
68	Typical Impaired Stream – Subcoregion 66j.....	93
69	Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 66j.....	94
70	Ecoregion 67 – Ridge & Valley.....	95
71	Discriminating Index Characteristic between Reference and Impaired Streams for Ecoregion 67	97
72	67f&i – Southern Limestone/Dolomite Valleys & Low Rolling Hills and Southern Dissected Ridges & Knobs.....	99
73	Typical Reference Stream – Subcoregion 67f&i	99
74	Typical Impaired Stream – Subcoregion 67f&i	100
75	Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 67f&i	101
76	67g – Southern Shale Valleys	102
77	Typical Reference Stream – Subcoregion 67g.....	103
78	Typical Impaired Stream – Subcoregion 67g	103



79	Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 67g.....	104
80	67h-Southern Sandstone Ridges	106
81	Typical Reference Stream – Subcoregion 67h.....	106
82	Typical Impaired Stream – Subcoregion 67h	107
83	Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 67h.....	108
84	68 – Southwestern Appalachians.....	109
85	Typical Reference Stream – Subcoregion 68c&d.....	110
86	Typical Impaired Stream – Subcoregion 68c&d	110
87	Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 68c&d.....	111
88	Ecoregion 75 – Southern Coastal Plain	113
89	Discriminating Index Characteristic between Reference and Impaired Streams for Ecoregion 75.....	114
90	75e – Okefenokee Plains	119
91	Typical Reference Stream – Subcoregion 75e.....	119
92	Typical Impaired Stream – Subcoregion 75e	120
93	Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 75e.....	121
94	75f – Sea Island Flatwoods.....	122
95	Typical Reference Stream – Subcoregion 75f.....	123
96	Typical Impaired Stream – Subcoregion 75f	123
97	Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 75f.....	124
98	75h – Bacon Terraces.....	126

99	Typical Reference Stream – Subecoregion 75h.....	126
100	Typical Impaired Stream – Subecoregion 75h	127
101	Discriminating Index Characteristic between Reference and Impaired Streams for Subecoregion 75h.....	128
102	75j-Sea Islands/Coastal Marsh	129
103	Typical Reference Stream – Subecoregion 75j.....	130
104	Typical Impaired Stream – Subecoregion 75j.....	130
105	Discriminating Index Characteristic between Reference and Impaired Streams for Subecoregion 75j.....	131
106	Discriminating Index Characteristic between Reference and Impaired Streams for Subecoregion 75j Nontidal.....	135
107	Discriminating Index Characteristic between Reference and Impaired Streams for Subecoregion 75j Tidal	137

LIST OF TABLES

Table	Page
1 Stream Rating	19
2 Index 45	20
3 Descriptive Statistics for Reference Streams in Ecoregion 45.....	21
4 Description of Numeric Ranking for Ecoregion 45.....	22
5 Stream Rating for Ecoregion 45	23
6 Index 45a	27
7 Descriptive Statistics for Reference Streams in Subcoregion 45a.....	27
8 Description of Numeric Ranking for Subcoregion 45a.....	28
9 Stream Rating for Subcoregion 45a	29
10 Index 45b	30
11 Descriptive Statistics for Reference Streams in Subcoregion 45b.....	31
12 Description of Numeric Ranking for Subcoregion 45b.....	32
13 Stream Rating for Subcoregion 45b	32
14 Index 45c.....	34
15 Descriptive Statistics for Reference Streams in Subcoregion 45c.....	35
16 Description of Numeric Ranking for Subcoregion 45c.....	36
17 Stream Rating for Subcoregion 45c	37
18 Index 45d	38

19	Descriptive Statistics for Reference Streams in Subcoregion 45d.....	39
20	Description of Numeric Ranking for Subcoregion 45d.....	40
21	Stream Rating for Subcoregion 45d.....	40
22	Index 45h	42
23	Descriptive Statistics for Reference Streams in Subcoregion 45h.....	43
24	Description of Numeric Ranking for Subcoregion 45h.....	44
25	Stream Rating for Subcoregion 45h.....	44
26	Index 65	45
27	Descriptive Statistics for Reference Streams in Ecoregion 65.....	46
28	Description of Numeric Ranking for Ecoregion 65.....	47
29	Stream Rating for Ecoregion 65	48
30	Index 65c.....	53
31	Descriptive Statistics for Reference Streams in Subcoregion 65c	53
32	Description of Numeric Ranking for Subcoregion 65c	54
33	Stream Rating for Subcoregion 65c	55
34	Index 65d	57
35	Descriptive Statistics for Reference Streams in Subcoregion 65d.....	57
36	Description of Numeric Ranking for Subcoregion 65d.....	58
37	Stream Rating for Subcoregion 65d	59
38	Index 65g	60

39	Descriptive Statistics for Reference Streams in Subcoregion 65g	61
40	Description of Numeric Ranking for Subcoregion 65g	62
41	Stream Rating for Subcoregion 65g	62
42	Index 65h	64
43	Descriptive Statistics for Reference Streams in Subcoregion 65h	65
44	Description of Numeric Ranking for Subcoregion 65h	66
45	Stream Rating for Subcoregion 65h	67
46	Index 65k	69
47	Descriptive Statistics for Reference Streams in Subcoregion 65k	69
48	Description of Numeric Ranking for Subcoregion 65k	70
49	Stream Rating for Subcoregion 65k	71
50	Index 65l	73
51	Descriptive Statistics for Reference Streams in Subcoregion 65l	73
52	Description of Numeric Ranking for Subcoregion 65l	74
53	Stream Rating for Subcoregion 65l	75
54	Index 65o	77
55	Descriptive Statistics for Reference Streams in Subcoregion 65o	78
56	Description of Numeric Ranking for Subcoregion 65o	79
57	Stream Rating for Subcoregion 65o	79
58	Index 66	80

59	Descriptive Statistics for Reference Streams in Ecoregion 66	81
60	Description of Numeric Ranking for Ecoregion 66	82
61	Stream Rating for Ecoregion 66	83
62	Index 66d	86
63	Descriptive Statistics for Reference Streams in Subcoregion 66d	86
64	Description of Numeric Ranking for Subcoregion 66d	87
65	Stream Rating for Subcoregion 66d	88
66	Index 66g	89
67	Descriptive Statistics for Reference Streams in Subcoregion 66g	90
68	Description of Numeric Ranking for Subcoregion 66g	91
69	Stream Rating for Subcoregion 66g	91
70	Index 66j	93
71	Descriptive Statistics for Reference Streams in Subcoregion 66j	93
72	Description of Numeric Ranking for Subcoregion 66j	94
73	Stream Rating for Subcoregion 66j	96
74	Index 67	96
75	Descriptive Statistics for Reference Streams in Ecoregion 67	96
76	Description of Numeric Ranking for Ecoregion 67	97
77	Stream Rating for Ecoregion 67	98
78	Index 67f&i	100

79	Descriptive Statistics for Reference Streams in Subecoregion 67f&l.....	100
80	Description of Numeric Ranking for Subecoregion 67f&i.....	101
81	Stream Rating for Subecoregion 67f&i.....	102
82	Index 67g	103
83	Descriptive Statistics for Reference Streams Subecoregion 67g	104
84	Description of Numeric Ranking for Subecoregion 67g.....	105
85	Stream Rating for Subecoregion 67g	105
86	Index 67h	107
87	Descriptive Statistics for Reference Streams in Subecoregion 67h	107
88	Description of Numeric Ranking for Subecoregion 67h.....	108
89	Stream Rating for Subecoregion 67g	109
90	Index 68c&d	110
91	Descriptive Statistics for Reference Streams in Subecoregion 68c&d	111
92	Description of Numeric Ranking for Subecoregion 68c&d.....	112
93	Stream Rating for Subecoregion 68c&d	112
94	Index 75	113
95	Descriptive Statistics for Reference Streams in Ecoregion 75.....	114
96	Description of Numeric Ranking for Ecoregion 75.....	115
97	Stream Rating for Ecoregion 75.....	116
98	Index 75e	120

99	Descriptive Statistics for Reference Streams in Subcoregion 75e	120
100	Description of Numeric Ranking for Subcoregion 75e	121
101	Stream Rating for Subcoregion 75e	122
102	Index 75f	123
103	Descriptive Statistics for Reference Streams in Subcoregion 75f	124
104	Description of Numeric Ranking for Subcoregion 75f.....	125
105	Stream Rating for Subcoregion 75f	125
106	Index 75h	127
107	Descriptive Statistics for Reference Streams in Subcoregion 75h	127
108	Description of Numeric Ranking for Subcoregion 75h.....	128
109	Stream Rating for Subcoregion 75h	129
110	Index 75j.....	130
111	Descriptive Statistics for Reference Streams in Subcoregion 75j	131
112	Description of Numeric Ranking for Subcoregion 75j.....	132
113	Stream Rating for Subcoregion 75j	133
114	Index 75j Nontidal.....	134
115	Descriptive Statistics for Reference Streams in Subcoregion 75j Nontidal	134
116	Description of Numeric Ranking for Subcoregion 75j Nontidal	135
117	Stream Rating for Subcoregion 75j Nontidal	136
118	Index 75j Tidal.....	136

119	Descriptive Statistics for Reference Streams in Subcoregion 75j Tidal	136
120	Description of Numeric Ranking for Subcoregion 75j Tidal	137
121	Stream Rating for Subcoregion 75j Tidal.....	138
122	Correlations between Index Scores and Percent Land Use: Ecoregion Level.....	138
123	Correlations between Index Scores and Percent Land Use: Subcoregion Level.....	139

Abstract

Using an ecoregional approach, multimetric indices were developed to describe stream condition in each geographically distinct region of Georgia. Collected from predetermined reference and impaired condition streams, macroinvertebrate data were used to develop multimetric indices. Multimetric indices identified a range of stream conditions, as well as, the overall health of aquatic ecosystems. Based on multimetric indices, the Multimetric Rating System grouped streams according to overall stream condition. The Multimetric Rating System used multiple indices to describe various facets of stream condition. Therefore, it may be concluded that the Multimetric Rating System is a robust water management tool that may be used to evaluate stream condition, determine water management decisions, and describe water quality criteria.

Introduction

As part of the Clean Water Act (CWA) Section 101 (a), it is the duty of each state to monitor and assess the chemical, physical, and biological conditions of streams within its boundaries. Therefore, states are required to consider the “biological integrity” of their waters when developing stream monitoring procedures (Berry 2000). Biotic indices are accepted by the Environmental Protection Agency as a method for assessing the biological health or condition of wadeable streams (Barbour et al. 1999).

States must also determine water quality standards for all water bodies as required by the CWA Section 305(b). Water quality standards establish designated use and criteria for each water body, which must be maintained for all waters within each state (Berry 2000). State agencies must first define water quality standards and then determine a method of monitoring these standards. In some states, biological indices have been used to assess and monitor streams in order to maintain water quality standards set by states throughout the United States (Barbour 1997).

Beginning in the 1970's with the CWA, biological monitoring has developed into a widely used tool for tracking the condition of water resources. In the United States, the chemical condition of water resources was the only consideration in monitoring and remediating processes before the 1970's (Berry 2000). During the last twenty years, the United States has made great improvements eliminating point-source pollution and, as a result, chemical contamination has been greatly reduced. Currently, the major impairment

concern for surface waters is non-point source pollution (Barbour 1997). Biological assessment has been found to be an equally effective tool for assessing both point and non-point source pollution (Karr 1991).

For waterbodies that have been shown to be impaired, states must develop a plan for returning that waterbody to an unimpaired status. Important regulatory controls, which are intended to accomplish this task, are Total Maximum Daily Loads (TMDLs) of target nonpoint source contaminants, ranging from metals and nutrients to suspended sediment. According to the CWA Section 303(d), state regulatory agencies must establish TMDLs for each water body that has not attained water quality standards after imposing technology-based controls (Barbour et al. 1999). Biological assessments of the structure and function of lotic communities can determine whether or not water quality standards have been achieved and if TMDLs are required for a specific water body.

A broadly applicable indicator for use in biological assessment is the Index of Biotic Integrity (IBI) (Karr 1981). The IBI approach was developed to identify levels of stream impairment using metrics based upon fish assemblages as biological indicators. Using the IBI as a model, many biomonitoring programs have expanded to incorporate several types of multimetric indices using fish, macroinvertebrates, and periphyton assemblage-level data. It has been shown that using multiple assemblages from various trophic levels can provide assessments of a broader array of stressors causing stream impairment (Karr 1991).

By monitoring biological indicators, such as the benthic macroinvertebrate community, researchers can describe a given stream or river condition. Macroinvertebrates are considered excellent indicators because they are relatively sedentary and thus can be used to assess long-term change and cumulative effects in a specific location and, depending upon the number of sampling locations and monitoring network design, biological indicators can be used in broader-scale assessments, such as catchments.

According to Murtaugh (1996), an indicator is considered effective if it is sensitive to stressors or other specific factors under observation. When investigating stream condition, macroinvertebrate community assemblages can provide researchers with a description of the stream's condition (Resh 1995). Stream community structures are altered by human disturbance and can be used to identify the type and level of disturbance encountered. Using ecological descriptors such as tolerance values, macroinvertebrate assemblages can describe the impairment level of a stream relative to the chosen reference condition (Barbour *et al.* 1999).

The Rapid Bioassessment Protocol (RBP) was developed as a cost-effective and time-efficient procedure for assessing wadeable streams (Barbour *et al.* 1999). In its most complete, but rarely applied form, the RBP uses fish, benthic macroinvertebrate, and periphyton assemblage-level data to develop a multimetric index, which is used as the indicator of stream impairment. Metrics are used to quantify different attributes of the stream biota (Jessup and Gerritsen 2000). The choice of final metrics ultimately used in an index is based, in part,

on their relationship to ecoregional characteristics and response to stressors (Barbour *et al.* 1999).

Several methods have been used to classify streams according to their abiotic characteristics. Ricker (1934) developed a stream classification for streams in Ontario, Canada based upon the size of the stream, substrate material, the diversity and abundance of the biota, and the physical and chemical characteristics of the water body. Ricker developed this system to group streams according to their similar abiotic characteristics. This technique was used to investigate streams with similar physical and chemical properties, therefore defining each stream's biological characteristics without biased abiotic information.

More recently, Omernik (1987) developed a map of ecoregions for the United States as a framework for grouping ecosystems, both aquatic and terrestrial. Ecoregional groups are based upon patterns of topography, geology and soil, and land use that are intended to minimize within-group variability and maximize among-group variability. For an index to be effective, abiotic differences such as variation in catchment geology must first be eliminated. Using the ecoregion approach, multimetric indices can be more easily calibrated to detect impairment (Jessup and Gerritsen 2000). Therefore, biotic indices are developed specifically for each ecoregion and the streams within are compared to assess each stream's condition (Paul and Gerritsen 2002).

Multimetric indices are used to describe the ecological characteristics and detect threats to biological integrity of a stream (Rankin 1994). Metrics from

richness, composition, tolerance/intolerance, and habitat/trophic biological categories are evaluated to determine their ability to detect differences in reference and impaired conditions. Streams are grouped according to their physical and chemical characteristics and are compared within groups. Usually between six to eight metrics are chosen for an index and assigned a quantitative index score for each stream. Based upon variation from the least impaired sites, the index score describes each stream relative to their level of impairment. Once a quantitative rating is assigned, the index score can be described by a qualitative rating.

Using quantitative index scores to describe streams within groups, narrative ratings describe stream characteristics qualitatively. Narrative ratings typically group streams into “good”, “fair”, and “poor” qualitative categories. Each stream is evaluated based on its potential to achieve the least impaired condition within each group. Qualitative measures of stream condition can be used to determine regulatory and monitoring needs of each stream. Using narrative biological criteria, monitoring agencies can determine action plans for stream conservation and restoration (Karr 1999).

In 1977, Hilsenhoff introduced his biotic index based on organic and nutrient tolerance levels of arthropods. Using one phylum, Hilsenhoff was able to simplify the bioassessment process. Hilsenhoff's biotic index was based upon a 100-individual sample in which each species or genus of arthropod was assigned a tolerance level. Once all individuals from each sample were identified, the

tolerance values were averaged together giving each stream a biotic index score (Hilsenhoff 1987).

Originally, the Clean Water Act (CWA) standard for adequate biological support was termed “fishable-swimmable” but this standard has evolved into a more functional “aquatic life-use” designation (Berry 2000). Multimetric indices can also be used to determine aquatic-life use designations; an EPA requirement for nonpoint source management. The Vermont Department of Environmental Conservation uses benthic and fish data, employing multimetric indices, to determine numeric biological criteria (Vermont Department of Environmental Conservation 2004). Numeric criteria are applied and are used to evaluate each water body according to aquatic life use designations. Being the quantitative equivalent of narrative biological criteria, numeric biological criteria can also be used to assess water quality standards.

Several states have developed narrative rating systems to numerically describe biological criteria. In Ohio, the Qualitative Habitat Evaluation Index (QHEI) was developed to determine the aquatic life potential of each water body (Rankin 1989). Each water body is assigned an aquatic use level, which could be applied to aquatic life use designations. The purpose of this system is to describe the physical, chemical, and biological properties of a water system, and therefore protect all facets of this system.

Narrative criteria are used to describe the waterbody’s condition or current state, which is based on quantitative data. The QHEI has two main categories of aquatic life uses: Warmwater Habitat (WWH) and Exceptional Warmwater

Habitat (EWH). The WWH is described as the typical habitat condition of rivers and streams in Ohio. The EWH is an aquatic habitat that is exceptional for its fauna and quality of habitat. Narrative criteria of exceptional (EWH), good (WWH), fair, poor, or very poor are assigned to each stream or river (Rankin 1989).

The Benthic Index of Stream Integrity (BISI), developed in Rockdale County, Georgia, assigns each stream with a quantitative rating (Tetra Tech 2001). Using a percentile method, the index score is described by a qualitative rating. Streams with an index score above the 25th percentile are equally divided into “good” and “very good” narrative ratings. Streams rated below the 25th percentile are divided into three groups: “fair”, “poor”, and “very poor”. Narrative ratings are used to describe biological characteristics that are found in each stream category.

With the use of multimetric indices, chemical analysis, and physical habitat assessment, stream assessment methods have been developed to identify the level of stream impairment. Once stream assessment is completed, this information can be used to determine regulatory and monitoring procedures for the study area. The evaluation of stream conditions is an important method for managing water resources (Barbour *et al.* 1999).

The Georgia Environmental Protection Division (GAEPD) began a multiphase project in 1996 to delineate the state into geographically similar Ecoregions. The primary objective of Phase I was to develop biological criteria for wadeable streams using an Ecoregional framework. Using this technique,

biota were sampled from areas with similar geology, land use/cover, vegetation, and topography. Once the level III Ecoregions were refined, as delineated by Omernik in 1987, the Ecoregions were further divided into level IV Ecoregions.

A final map of Georgia's Ecoregions was presented in June 2000 depicting the multiple regions and potential reference sites selected. Based on Ecoregions developed in Phase I, Phase II developed a system for selecting reference sites based on land use data. Reference sites were selected from each Ecoregion level using an unbiased method. For each Ecoregion, the reference condition established a baseline condition describing the resident biota and stream status. A report detailing reference conditions and multimetric indices was produced in 2004 (Gore *et al.* 2004).

Using Rapid Bioassessment techniques, Phase III described the impaired condition of streams in Georgia. For quality control, a random selection of reference sites was resampled to verify the findings from Phase II. As with reference sites in Phase II, impaired sites were selected via GIS land use data. Using the data from Phase II and Phase III, a numeric scoring system was developed to compare streams within an Ecoregion, identify trends, and validate the results of this study.

Methods

The complete methods used for data collection are found in the Quality Assurance Project Plan (QAPP): Ecoregions Reference Site Project for Wadeable Streams in Georgia (Columbus State University 2000). Streams were sampled in all six ecoregions of Georgia and 25 subecoregions including all except three: the Okefenokee Swamp (75g) and Floodplains and Low Terraces (65p and 75i). A total of 111 reference sites and 184 impaired sites were sampled and considered in the developed indices (Omernik 1987). The subecoregions used in this study were taken from the Draft Level IV Sub-Ecoregions of Georgia (Griffith *et al.* 2001).

The sampling phase took place over a two-year period, with all field work occurring between September and February, the designated "index period". Within each stream, a hundred meter reach was sampled, water and macroinvertebrate samples were collected, and a habitat assessment was completed.

Stream sites were selected primarily by Geographic Information Systems (GIS) analysis of land use/land cover data to determine catchment level disturbance (Olson 2001, Gore *et al.* 2004). Once field teams arrived at a stream site, stream condition was evaluated to confirm the GIS designation. Each sample site did not include any major tributaries and was located at least a hundred meters from stream obstructions to reduce instream disturbances.

Macroinvertebrates were collected by the means of a D-frame net using the twenty-jab method (Georgia Bioassessment Protocol). A net mesh size of

595-600 microns was used. Macroinvertebrates were sampled in all habitats including: fast and slow riffles, undercut banks, leaf material, snags, and sandy bottoms. The sampling procedure started at the zero meter mark and continued upstream to reduce habitat disturbance (Columbus State University 2000).

Water samples for laboratory analytical chemistry were collected according to procedures in the Quality Assurance Project Plan (QAPP) (Columbus State University 2000) and were labeled, preserved, and chilled until returned to the lab. Macroinvertebrate samples were transferred to one liter bottles, labeled, and preserved in 95% ethyl alcohol.

From each macroinvertebrate sample, a 200-organism subsample was randomly selected. The original composite sample, taken from all habitats, was evenly spread upon a Caton gridded screen (Caton 1991). Sample squares were chosen using a random number sheet. Each grid square was checked for organisms until all are removed. At least four grids were taken from each sample and then continuously selected until 200 organisms were collected. Once subsampling was complete, macroinvertebrates were identified to the lowest possible taxonomic level.

Based on the raw macroinvertebrate data, a multimetric analysis calculated by *Ecological Data Application System* (EDAS) (MS Access 2000; Tetra Tech Inc. 2001) was used to assess stream condition. Metrics were selected from the following categories of biological information: richness, composition, tolerance/intolerance, and habit/trophic measures, so that each

category was represented when possible. Metrics were grouped into candidate indices for each ecoregion (Gore *et al.* 2004).

The following protocol was used for developing ecoregion based multimetric indices and subsequent rating system. All data were entered, quality checked, and metrics calculated using EDAS (MS Access 2000; Tetra Tech Inc. 2001). *Statistica* (Statsoft Inc. 2000) was used to run the Pearson Product-Moment Correlation and box-and-whisker plots (MDEQ 2003). The Pearson Product-Moment Correlation was used to determine redundancy among metrics. If metrics were too similar, one was eliminated to avoid describing the same ecological characteristic multiple times. Box-and-whisker plots were used to demonstrate the ability of different indices to discriminate between reference and various levels of impaired stream conditions. Desirable indices showed a complete separation in box-and-whisker plots (i.e., no overlap of interquartile ranges) between reference and impaired conditions (see Gore *et al.* (2004), for an expanded description of this procedure).

First, candidate metrics were selected from each biological category, when possible, and calculated in EDAS. Metric data were exported to Excel spreadsheets and the discrimination efficiency and the percentile distribution for each metric were determined. The discrimination efficiency (DE) was determined as follows (MDEQ 2003).

For metrics that increase with stress:

$$DE = \frac{\text{number of impaired sites} > \text{the 75}^{\text{th}} \text{ percentile of reference sites}}{\text{total number of impaired sites}}$$

For metrics that decrease with stress:

$$DE = \frac{\text{number of impaired sites} < \text{the 25}^{\text{th}} \text{ percentile of reference sites}}{\text{total number of impaired sites}}$$

Metric data were exported to *Statistica*. Once in *Statistica*, reference and impaired conditions were compared using box-and-whisker plots and product-moment correlation (MDEQ 2003). Metrics that revealed low discrimination ability in box-and-whiskers plots were not considered for candidate indices.

When two metrics were calculated as having a Pearson Product-Moment Correlation of greater than 0.90 or less than -0.90, one was automatically eliminated from candidate metrics because of redundancy with other metrics. Metrics with 0.80 to 0.90 Pearson Product-Moment Correlation Coefficient or -0.80 to -0.90 were considered as candidate metrics if the relationship was not similar to other metrics. If candidate metrics had a parallel linear relationship, their relationship was considered to be co-dependent and thus the information provided by that particular metric did not provide additional discrimination. When metrics with linear relationships were encountered, one was eliminated. Once undesirable metrics were eliminated, final candidate metric scores were standardized to a 100-point scale (MDEQ 2003).

From final candidate metric scores, several candidate indices were selected, each including four to seven metrics. Metrics were selected to represent each structural and behavioral category, to discriminate between reference and stressed conditions, and to produce unique information for each index. Each index was compared using the discrimination efficiency and box-

and-whisker plots. The discrimination efficiency and box-and-whisker plots revealed whether or not each candidate index discriminated between reference and impaired conditions. The index with the greatest discrimination ability was selected (MDEQ 2003). Selection of the final indices considered the metric selection criteria and chemical and physical data. Any other selection criteria were based on best professional judgment. The ideal index had a box-and-whisker plot with good discrimination efficiency, little or no overlap between reference and impaired conditions, allowed detection of stream impairment, and ranked relative severity of impairment.

Benthic indices were developed for each ecoregion and subcoregion. In ecoregion 75, additional indices were created by grouping tidal and non-tidal streams in subcoregion 75j (including one tidal stream from subcoregion 75f). By grouping tidal and non-tidal streams, indices were found to have higher discrimination efficiencies.

In each index, each stream received an index score. The index score is the average of all standardized metric values used in the index. Each stream also ranked, described, and rated. A stream receives a ranking between 1 and 5, which corresponds with a narrative description of very good, good, fair, poor, and very poor. The final analytical product was the formulation of a numeric rating system for wadeable streams in the state of Georgia, in the context of ecoregional or subcoregional differences. The stream's rating combines the two top categories of very good and good for an "A" rating, fair for a "B" rating, and poor and very poor for a "C" rating.

Results

It was found that subecoregion level indices had higher discrimination efficiencies than ecoregion level indices. Subecoregions with smaller catchment areas tended to have higher discrimination efficiencies than subecoregions with larger catchment areas. Indices for ecoregions in the piedmont and mountain areas (45, 65, 66, 67, and 68) tended to have metrics from all categories, especially richness. In the coastal plains (65 and 75), indices were developed primarily from metric in the composition category and rarely from richness category.

The following streams were excluded from reference sites, because each had at one least characteristic that was not allowed for a reference site: 45c-18, 45d-8, 65g-82, 65g-83, 67g-2, 75j-29. These site were not used in index development, but were included in the final stream rating.

The Multimetric Rating System can be applied to biocriteria development for water management purposes. By determining a threshold of discrimination between impaired and least impaired conditions, streams can be divided into management categories. The following thresholds were established: the 75th percentile for the least impaired condition and the 25th percentile for the most impaired condition. Using these thresholds, water resources managers can make scientifically based water management decisions.

Streams were grouped into three categories to simplify the ranking system for management purposes. In some cases, there was little difference in index



scores between streams of two different categories. The chance of rating error was reduced by grouping streams into three categories.

Categories "1" and "2" of the numeric ranking system were combined to create a group of least impaired sites ("A" rated streams). Least impaired sites require periodic monitoring to evaluate change over time relative to the reference condition. Category "3" ("B" rated streams) encompasses the majority of streams, which vary widely in their numeric range. Category "B" rated streams are impaired streams which require frequent attention to monitor condition change over time. Streams described as "poor" and "very poor" were combined into one group for severely impaired sites ("C" rated streams). Severely impaired sites require frequent monitoring to determine restoration needs and success of restoration attempts.

The Multimetric Rating System was developed based on a percentile method. In each ecoregion, streams with index scores above or equal to the 95th percentile were given the numeric value of "1" or described as having a "very good" stream condition. Index scores, which fell below the 95th percentile yet were equal to or above the 75th percentile received a numeric value of "2" or were described as having a "good" stream condition. Streams with index scores below the 75th percentile and above the 25th percentile received a "fair" stream narrative description. The "poor" description was assigned to streams with index scores equal to or below the 25th percentile yet above the 5th percentile. For streams equal to or below the 5th percentile, the "very poor" narrative description was assigned.

Figure 1. Level III & Level IV Ecoregions of Georgia.

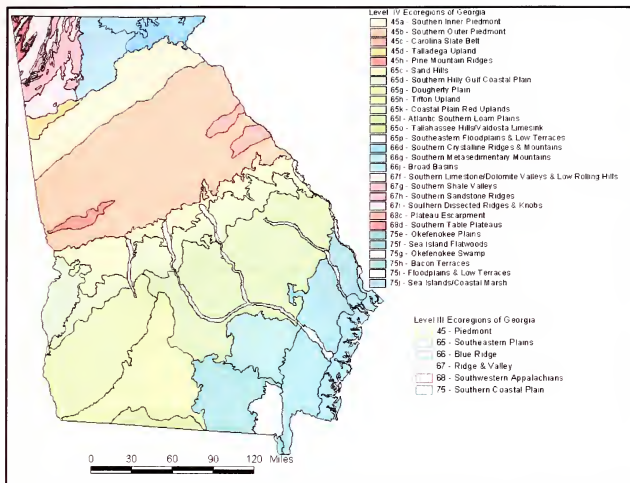


Figure 2. Georgia Ecoregions Reference Sites Sampled.

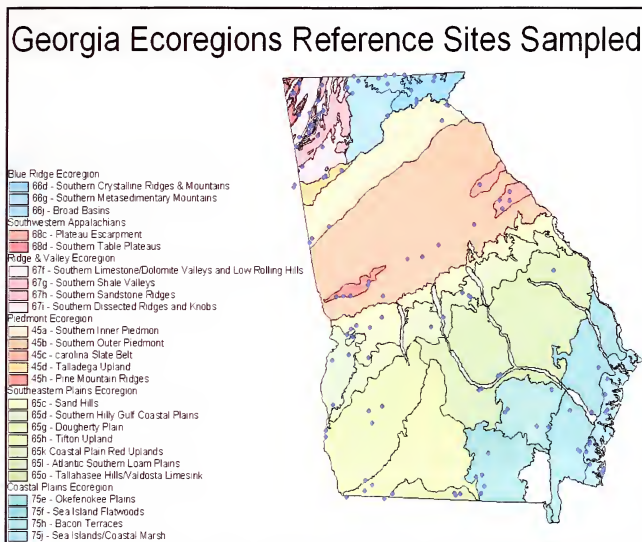


Figure 3. Georgia Ecoregions Impaired Sites Sampled.

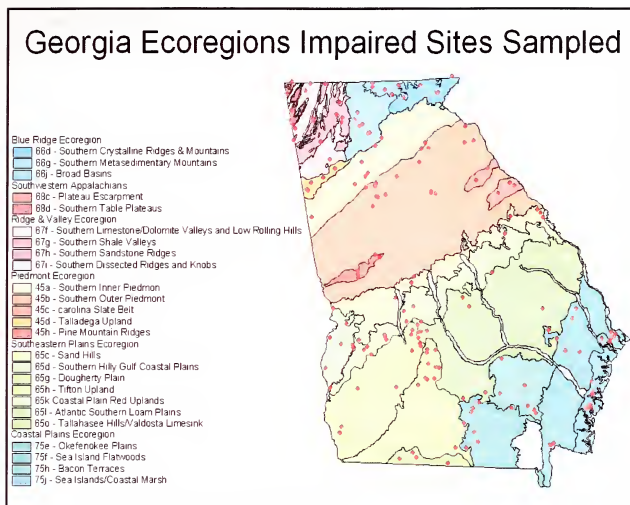


Table 1. Stream Rating. Stream Rating is based on the Numeric Ranking.

Numeric Ranking	Stream Rating	Management Decision
1	A	Continue periodic monitoring to detect change baseline reference condition
2		
3	B	Frequent monitoring critical to detect change in ecological status, lower range especially
4	C	Frequent monitoring necessary to determine remediation needs and if remediation has been successful
5		

Figure 4. Ecoregion 45 – Piedmont.

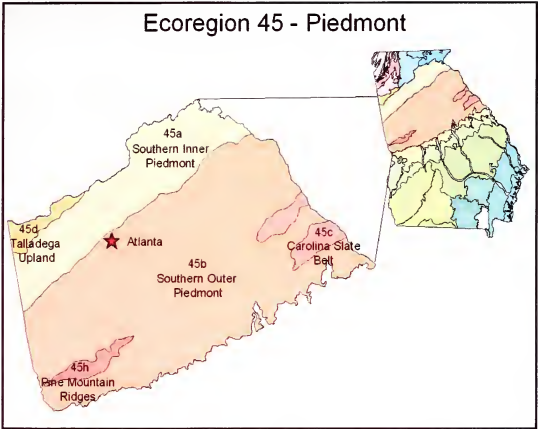


Table 2. Index 45.

Metric	Metric Category
Coleoptera Taxa	Richness
% Chironomidae	Composition
% Plecoptera	
% Intolerant Individuals	Tolerance / Intolerance
North Carolina Biotic Index (NCBI)	

Table 3. Descriptive Statistics for Reference Streams in Ecoregion 45. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n=23					Maximum
			5th	25th	50th	75th	95th	
Coleoptera Taxa	0.6	0.0	1.1	4.5	5.0	8.0	10.8	12.0
% Chironomidae	0.7	3.0	7.4	19.6	33.2	41.6	58.2	59.6
% Plecoptera	0.7	0.4	0.4	3.4	6.9	15.5	38.9	74.1
% Intolerant Individuals	0.6	3.4	4.0	13.6	23.3	31.2	50.1	78.0
North Carolina Biotic Index (NCBI)	0.6	2.1	3.9	4.8	5.4	6.2	7.7	7.8

Figure 5. Discriminating Index Characteristic between Reference and Impaired Streams for Ecoregion 45.

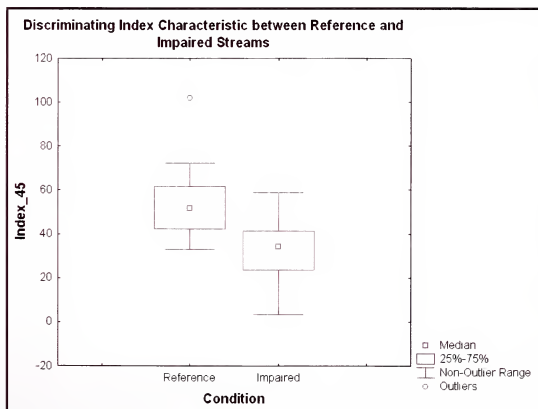


Table 4. Description of Numeric Ranking for Ecoregion 45. n=all reference and impaired sites in ecoregion 45.

Index Score	Numeric Ranking	Percentile n= 65
67 and above	1	Above 95 th
50-66	2	Below 95 th , Above 75 th
31-49	3	Below 75 th , Above 25 th
12-30	4	Below 25 th , Above 5 th
11 and below	5	Below 5 th

Table 5. Stream Rating for Ecoregion 45.

Stream	StationID	Sub-ecoregion	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Terrapin Creek	45d-15	45d	Reference	95	1	very good	A
Hillabatchee Creek	45a-89	45a	Reference	72	1	very good	A
Sparks Creek	45h-13	45h	Reference	71	1	very good	A
Davidson Creek	45a-3	45a	Reference	69	1	very good	A
Town Creek	HH16	45a	Reference	62	2	good	A
Murder Creek	45b-152	45b	Reference	62	2	good	A
Big Creek	45d-14	45d	Impaired	59	2	good	A
West Fork							A
Pumpkinvine Creek	45d-4	45d	Reference	57	2	good	A
Wallace Creek	45d-16	45d	Reference	57	2	good	A
Bull Creek	45c-19	45c	Reference	56	2	good	A
Three Mile Creek	45h-1	45h	Impaired	56	2	good	A
Mountain Creek	45a-90	45a	Impaired	54	2	good	A
Simpson Creek	45d-9	45d	Reference	53	2	good	A
Dry Fork	45c-8	45c	Reference	53	2	good	A
Mud Creek	45h-9	45h	Reference	52	2	good	A
Turkey Creek	45h-6	45h	Reference	50	2	good	A
Mann Creek	45d-21	45d	Impaired	50	2	good	A
Swinney Branch	45d-11	45d	Impaired	50	2	good	A
Kemp Creek	45c-16	45c	Reference	49	3	fair	B
Rocky Creek	45b-258	45b	Reference	49	3	fair	B
Pond Fork	45a-38	45a	Impaired	47	3	fair	B
Barnes Creek	45h-17	45h	Reference	47	3	fair	B
Little Sandy Creek	45b-1214	45b	Impaired	46	3	fair	B
Smithwick Creek	45a-35	45a	Impaired	46	3	fair	B
Copeland Creek	HH22	45b	Reference	44	3	fair	B
Snapping Creek	45b-201	45b	Impaired	43	3	fair	B
Trib to Flint River	45b-357	45b	Reference	42	3	fair	B

Table 5. Stream Rating for Ecoregion 45 (cont.).

Pegamore Creek	45d-6	45d	Impaired	41	3	fair	B
Pigeon Creek	45h-11	45h	Impaired	40	3	fair	B
Whooping Creek	HH18	45a	Reference	40	3	fair	B
Williams Creek	45h-16	45h	Reference	40	3	fair	B
Little Beaverdam Creek	45b-10	45b	Impaired	39	3	fair	B
Greene Creek	45d-23	45d	Impaired	39	3	fair	B
Upton Creek	45c-17	45c	Impaired	37	3	fair	B
Middle Fork Broad River	45a03//	45a	Reference	36	3	fair	B
Indian Creek	45b-116	45b	Impaired	35	3	fair	B
Double Branch	45b-3	45b	Impaired	35	3	fair	B
Powder Creek	45h-2	45h	Impaired	34	3	fair	B
Thompson Creek	45d-8	45d	Ref/Removed	34	3	fair	B
Candler Creek	45a-31	45a	Impaired	34	3	fair	B
Centerville Branch	45c-7	45c	Impaired	34	3	fair	B
Florence Creek	//4	45c	Reference	33	3	fair	B
Little Falling Creek	45b-156	45b	Reference	33	3	fair	B
Big Sandy Creek	45b-1213	45b	Impaired	33	3	fair	B
Trib to North Oconee River	45b-44	45b	Impaired	32	3	fair	B
Cherokee Creek	45c-10	45c	Impaired	31	3	fair	B
South River	45b-213	45b	Impaired	30	4	poor	C
Shoal Creek	45b-1	45b	Impaired	29	4	poor	C
Chickasaw Creek	45c-3	45c	Impaired	29	4	poor	C
Trib to Yellow River	45b-193	45b	Impaired	25	4	poor	C
Dry Fork Creek	45c-11	45c	Impaired	25	4	poor	C
Little Coldwater Creek	45b-13	45b	Impaired	24	4	poor	C
Sugar Creek	45b-212	45b	Impaired	23	4	poor	C

Table 5. Stream Rating for Ecoregion 45 (cont.).

South Fork	45b-203	45b	Impaired	23	4	poor	C
Olley Creek	45a-61	45a	Impaired	22	4	poor	C
Trib to Rocky Creek	45c-18	45c	Ref/Removed	20	4	poor	C
Coleachee Creek	45h-10	45h	Impaired	19	4	poor	C
Sope Creek	45a-55	45a	Impaired	17	4	poor	C
North Fork	45b-202	45b	Impaired	12	4	poor	C
Noonday Creek	45a-50	45a	Impaired	11	5	very poor	C
Rottenwood Creek	45a-59	45a	Impaired	8	5	very poor	C
Flint River	45b-217	45b	Impaired	5	5	very poor	C
Proctor Creek	45b-291	45b	Impaired	4	5	very poor	C

Figure 6. 45a – Southern Inner Piedmont.

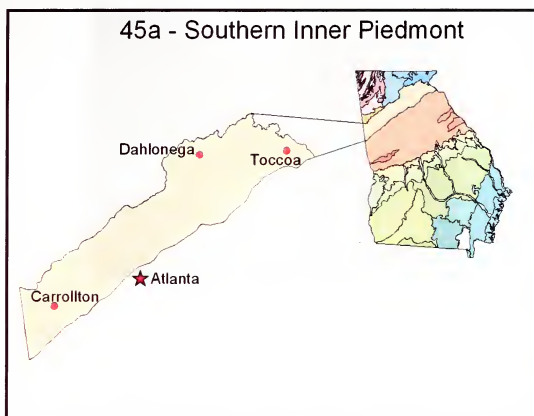


Figure 7. Typical Reference Stream – Subecoregion 45a.

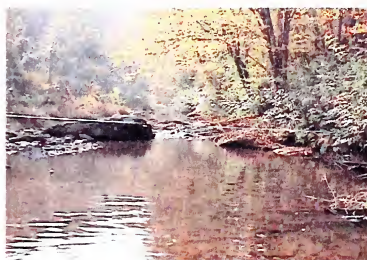


Figure 8. Typical Impaired Stream –Subcoregion 45a.



Table 6. Index 45a.

Metric	Metric Category
Plecoptera Taxa	Richness
% Tricoptera	Composition
% Chironomus Cricotopus/TC	
Tolerant Taxa	Tolerance
% Scraper	Functional Feeding Group
Clinger Taxa	Habitat

Table 7. Descriptive Statistics for Reference Streams in Subcoregion 45a. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 5					Maximum
			5th	25th	50th	75th	95th	
Plecoptera Taxa	.50	1.0	1.0	2.0	3.0	4.0	5.6	6.0
% Tricoptera	.75	4.0	6.0	13.8	14.8	18.8	31.8	35.0
% Chironomus Cricotopus/TC	1.0	0	0	0	0	0	0	0
Tolerant Taxa	1.0	7.0	7.0	7.0	7.0	8.0	10.4	11.0
% Scraper	.75	3.0	5.0	11.8	15.3	31.8	39.9	42.0
Clinger Taxa	.88	9.0	10.0	14.0	15.0	19.0	19.8	20.0

Figure 9. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 45a.

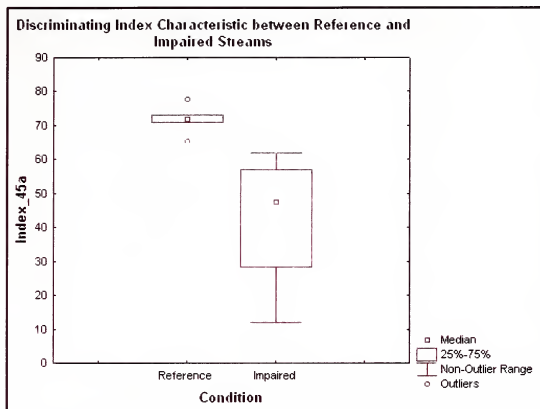


Table 8. Description of Numeric Ranking for Subcoregion 45a. n=all reference and impaired sites in subcoregion 45a.

Index Score	Numeric Ranking	Percentile n= 13
75 and above	1	Above 95 th
71-74	2	Below 95 th , Above 75 th
43-70	3	Below 75 th , Above 25 th
19-42	4	Below 25 th , Above 5 th
19 and below	5	Below 5 th

Table 9. Stream Rating for Subcoregion 45a.

Stream	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Town Creek	Reference	78	1	very good	A
Davidson Creek	Reference	73	2	good	A
Middle Fork Broad River	Reference	72	2	good	A
Hillabahatchee Creek	Reference	71	2	good	A
Whooping Creek	Reference	65	3	fair	B
Pond Fork	Impaired	62	3	fair	B
Smithwick Creek	Impaired	59	3	fair	B
Mountain Creek	Impaired	56	3	fair	B
Candler Creek	Impaired	53	3	fair	B
Sope Creek	Impaired	43	3	fair	B
Noonday Creek	Impaired	33	4	poor	C
Rottenwood Creek	Impaired	24	4	poor	C
Olley Creek	Impaired	12	5	very poor	C

Figure 10. 45b – Southern Outer Piedmont.

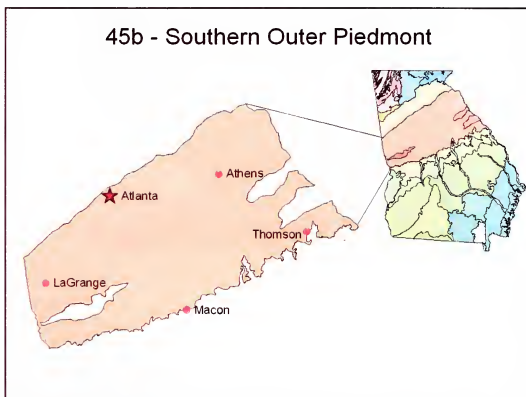


Figure 11. Typical Reference Stream – Subcoregion 45b.



Figure 12. Typical Impaired Stream – Subcoregion 45b.



Table 10. Index 45b.

Metric	Metric Category
Coleoptera Taxa	Richness
% Oligochaeta	Composition
% Plecoptera	
Shredder Taxa	Functional Feeding Group
Scraper Taxa	
Swimmer Taxa	Habitat

Table 11. Descriptive Statistics for Reference Streams in Subcoregion 45b. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n=5					Maximum
			5th	25th	50th	75th	95th	
Coleoptera Taxa	0.9	5.0	5.2	6.0	6.0	8.0	8.8	9.0
% Oligochaeta	0.8	0.0	0.0	0.0	0.8	1.2	2.9	3.0
% Plecoptera	0.8	1.0	2.0	4.6	10.8	12.9	16.2	17.0
Shredder Taxa	0.9	4.0	4.4	6.0	6.0	7.0	11.0	12.0
Scraper Taxa	0.9	2.0	2.4	4.0	6.0	8.0	8.8	9.0
Swimmer Taxa	0.9	1.0	1.4	3.0	3.0	3.0	3.8	4.0

Figure 13. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 45b.

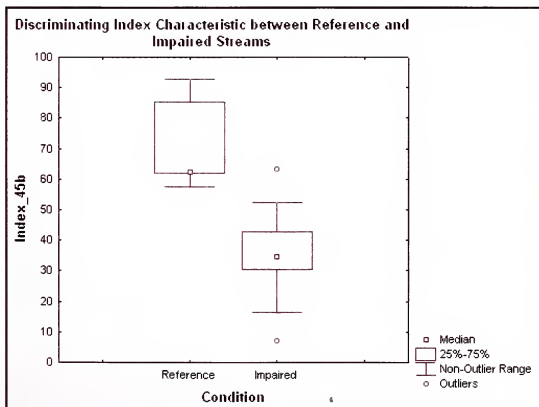


Table 12. Description of Numeric Ranking for Subcoregion 45b. n=all reference and impaired sites in subcoregion 45b.

Index Score	Numeric Ranking	Percentile n= 22
84 and above	1	Above 95 th
56-83	2	Below 95 th , Above 75 th
32-55	3	Below 75 th , Above 25 th
17-31	4	Below 25 th , Above 5 th
16 and below	5	Below 5 th

Table 13. Stream Rating for Subcoregion 45b.

Stream	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Rocky Creek	Reference	93	1	very good	A
Murder Creek	Reference	85	1	very good	A
Beaverdam Creek	Impaired	63	2	good	A
Copeland Creek	Reference	62	2	good	A
Trib to Flint River	Reference	62	2	good	A
Little Falling Creek	Reference	58	2	good	A
Indian Creek	Impaired	53	3	fair	B
Trib to North Oconee River	Impaired	51	3	fair	B
Little Sandy Creek	Impaired	46	3	fair	B
Little Beaverdam Creek	Impaired	43	3	fair	B
Little Coldwater Creek	Impaired	39	3	fair	B
Shoal Creek	Impaired	38	3	fair	B
Proctor Creek	Impaired	35	3	fair	B
Double Branch	Impaired	34	3	fair	B
Big Sandy Creek	Impaired	34	3	fair	B
Trib to Yellow River	Impaired	31	4	poor	C
Snappfinger Creek	Impaired	31	4	poor	C
South Fork	Impaired	30	4	poor	C
North Fork	Impaired	23	4	poor	C
Flint River	Impaired	20	4	poor	C
South River	Impaired	16	5	very poor	C
Sugar Creek	Impaired	7	5	very poor	C

Figure 14. 45c – Carolina Slate Belt.

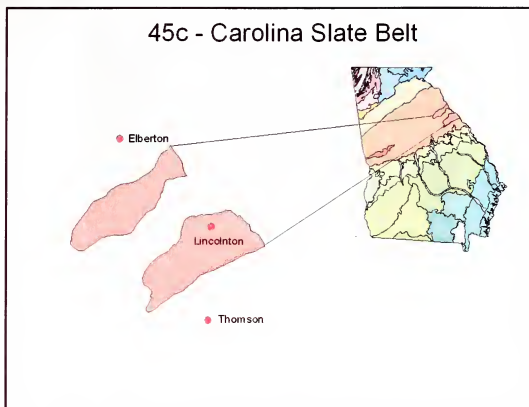


Figure 15. Typical Reference Stream – Subcoregion 45c.



Figure 16. Typical Impaired Stream – Subecoregion 45c.



Table 14. Index 45c.

Metric	Metric Category
Tanytarsini Taxa	Richness
% Odonata	Composition
% Tanypodinae/ Total Chironomidae	
Dominant Individual	Tolerance
% Intolerant Individuals	
% Shredder	Functional Feeding Group
Swimmer Taxa	Habitat

Table 15. Descriptive Statistics for Reference Streams in Subcoregion 45c. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n=4					Maximum
			5th	25th	50th	75th	95th	
Tanytarsini Taxa	0.6	0.0	0.5	2.3	4.0	5.5	6.7	7.0
% Odonata	0.6	0.0	0.4	0.5	1.0	1.5	1.7	2.0
% Tanytopodinae/TC	0.6	4.0	4.0	5.0	6.7	8.8	10.9	11.0
Dominant Individual	0.6	35.0	35.5	37.3	46.0	55.3	58.3	59.0
% Intolerant Individuals	0.8	3.0	7.2	22.6	31.2	33.5	33.5	34.0
% Shredder	1.0	1.0	2.3	6.5	16.3	25.7	28.7	29.0
Swimmer Taxa	0.4	2.0	2.2	2.8	3.5	4.0	4.0	4.0

Figure 17. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 45c.

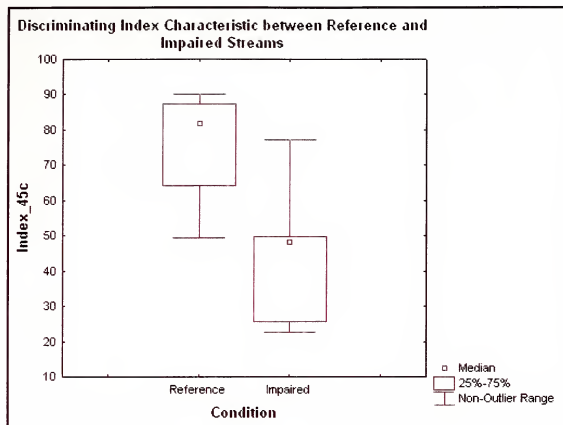


Table 16. Description of Numeric Ranking for Subcoregion 45c. n=all reference and impaired sites in subcoregion 45c.

Index Score	Numeric Ranking	Percentile n = 10
88 and above	1	Above 95th
79-87	2	Below 95 th , Above 75th
49-78	3	Below 75 th , Above 25th
25-48	4	Below 25 th , Above 5th
24 and below	5	Below 5th

Table 17. Stream Rating for Subcoregion 45c.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Kemp Creek	45c-16	Reference	90	1	very good	A
Dry Fork	45c-8	Reference	85	1	very good	A
Bull Creek	45c-19	Reference	79	2	good	A
Centerville Branch	45c-7	Impaired	77	3	fair	B
Trib to Rocky Creek	45c-18	Ref/Removed	55	3	fair	B
Chickasaw Creek	45c-3	Impaired	50	3	fair	B
Florence Creek	//4	Reference	49	3	fair	B
Dry Fork Creek	45c-11	Impaired	48	4	poor	C
Upton Creek	45c-17	Impaired	26	4	poor	C
Cherokee Creek	45c-10	Impaired	23	5	very poor	C

Figure 18. 45d – Talladega Upland.

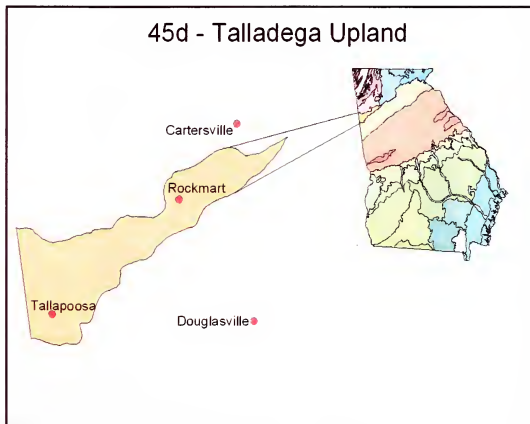


Figure 19. Typical Reference Stream Subecoregion 45d.

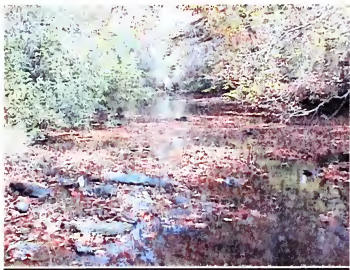


Figure 20. Typical Impaired Stream – Subecoregion 45d.



Table 18. Index 45d.

Metric	Metric Category
Coleoptera Taxa	Richness
% Tanypodinae/ Total Chironomidae	Composition
% Odonata	
North Carolina Biotic Index (NCBI)	Tolerance
% Tolerant Individuals	
Shredder Taxa	Functional Feeding Group

Table 19. Descriptive Statistics for Reference Streams in Subcoregion 45d. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n=4					Maximum
			5th	25th	50th	75th	95th	
Coleoptera Taxa	0.8	2.0	2.9	6.5	8.0	8.3	8.9	9.0
% Tanypodinae/ TC	1.0	1.5	1.6	2.0	2.3	5.4	12.5	14.3
% Odonata	0.8	0.0	0.2	1.1	1.5	1.8	2.7	2.9
NCBI	1.0	2.1	2.3	3.4	3.9	4.1	4.5	4.6
% Tolerant Individuals	1.0	6.2	6.4	7.2	8.0	8.5	8.6	8.6
Shredder Taxa	0.4	6.0	6.0	6.0	6.0	6.8	8.6	9.0

Figure 21. Discriminating Index Characterization between Reference and Impaired Streams for Subcoregion 45d.

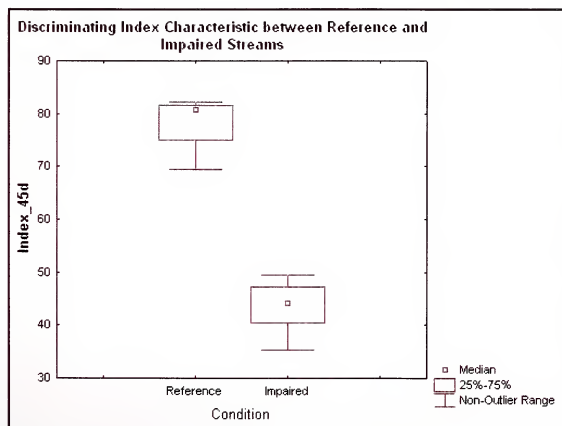


Table 20. Description of Numeric Ranking for Subcoregion 45d. n=all reference and impaired sites in subcoregion 45d.

Index Score	Numeric Ranking	Percentile n = 9
82 and above	1	Above 95 th
78-81	2	Below 95 th , Above 75 th
44-77	3	Below 75 th , Above 25 th
38-43	4	Below 25 th , Above 5 th
37 and below	5	Below 5 th

Table 21. Stream Rating for Subcoregion 45d.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Terrapin Creek	45d-9	Reference	82	1	very good	A
Wallace Creek	45d-16	Reference	81	2	good	A
West Fork Pumpkinvine Creek	45d-15	Reference	81	2	good	A
Simpson Creek	45d-4	Reference	70	3	fair	B
Swinney Branch	45d-21	Impaired	50	3	fair	B
Big Creek	45d-14	Impaired	47	3	fair	B
Mann Creek	45d-8	Ref/Removed	45	3	fair	B
Greene Creek	45d-6	Impaired	44	3	fair	B
Pegamore Creek	45d-11	Impaired	40	4	poor	C
Thompson Creek	45d-23	Impaired	35	5	very poor	C

Figure 22. Subcoregion 45h – Pine Mountain Ridges.

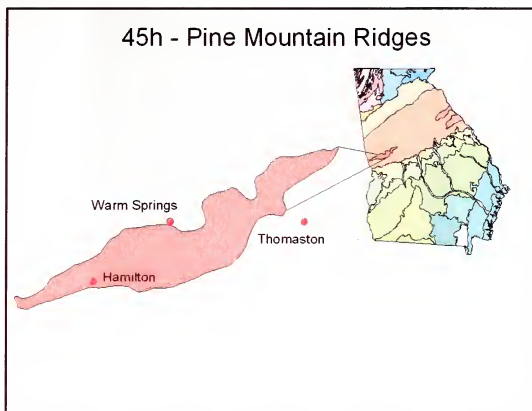


Figure 23. Typical Reference Stream – Subcoregion 45h.



Figure 24. Typical Impaired Stream – Subcoregion 45h.



Table 22. Index 45h.

Metric	Metric Category
Plecoptera Taxa	Richness
% Ephemeroptera	Composition
% Plecoptera	
% Intolerant Individuals	Tolerance
% Scraper	Functional Feeding Group
% Clinger	Habitat

Table 23. Descriptive Statistics for Reference Streams in Subcoregion 45h. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 5					Maximum
			5th	25th	50th	75th	95th	
Plecoptera Taxa	1.0	2.0	2.4	4.0	4.0	6.0	6.8	7.0
% Ephemeroptera	0.8	9.0	9.4	10.8	12.1	13.8	16.3	17.0
% Plecoptera	0.8	3.0	3.1	5.6	5.8	13.3	13.9	14.0
% Intolerant Individual	0.8	17.0	17.5	20.0	20.8	25.4	40.3	44.1
% Scraper	0.6	4.0	4.8	7.3	8.8	12.5	15.5	16.3
% Clinger	0.6	28.7	29.8	34.6	50.0	55.0	59.8	61.0

Figure 25. Discriminating Index Characteristic between Reference and Impaired Streams for 45h.

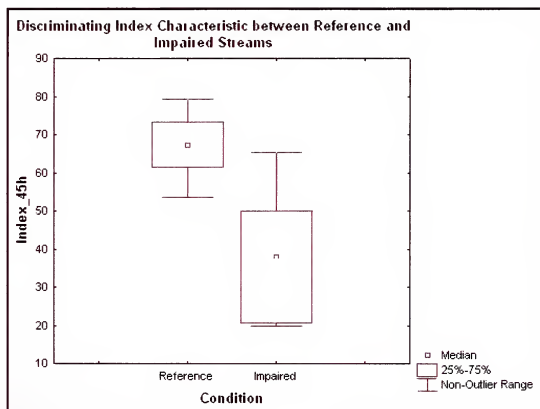


Table 24. Description of Numeric Ranking for Subcoregion 45h. n=all reference and impaired sites in subcoregion 45h.

Index Score	Numeric Ranking	Percentile n = 10
77 and above	1	Above 95th
67-76	2	Below 95 th , Above 75th
41-66	3	Below 75 th , Above 25th
21-40	4	Below 25 th , Above 5th
20 and below	5	Below 5th

Table 25. Stream Rating for Subcoregion 45h.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Sparks Creek	45h-13	Reference	79	1	very good	A
Mud Creek	45h-9	Reference	73	2	good	A
Williams Creek	45h-16	Reference	67	2	good	A
Three Mile Creek	45h-1	Impaired	65	3	fair	B
Barnes Creek	45h-17	Reference	62	3	fair	B
Turkey Creek	45h-6	Reference	54	3	fair	B
Lazar Creek	45h-12	Impaired	50	3	fair	B
Pigeon Creek	45h-11	Impaired	38	4	poor	C
Coleachee Creek	45h-10	Impaired	21	4	poor	C
Powder Creek	45h-2	Impaired	20	5	very poor	C

Figure 26. Ecoregion 65 – Southeastern Plains.

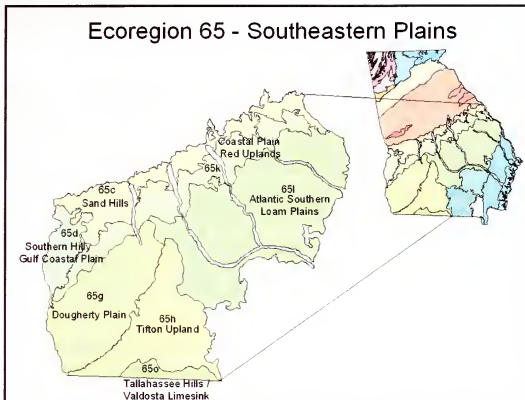


Table 26. Index 65.

Metric	Metric Category
% Coleoptera	Composition
% Oligochaeta	
Intolerant Taxa	Tolerance
% Intolerant Individuals	
% Predator	Functional Feeding Group
% Clinger	Habitat

Table 27. Descriptive Statistics for Reference Streams in Ecoregion 65. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 32					Maximum
			5th	25th	50th	75th	95th	
% Coleoptera	0.5	0.0	0.2	2.0	4.6	9.8	17.8	36.4
% Oligochaeta	0.6	0.0	0.0	0.0	1.4	2.9	10.4	11.7
Intolerant Taxa	0.5	0.0	0.0	2.0	3.5	6.0	9.9	12.0
% Intolerant Individuals	0.6	0.0	0.0	2.5	6.4	13.6	36.23	46.7
% Predator	0.5	1.5	3.1	7.5	11.8	19.3	38.5	48.8
% Clinger	0.5	0.0	2.5	8.1	18.8	27.6	47.8	63.3

Figure 27. Discriminating Index Characteristic between Reference and Impaired Streams for Ecoregion 65.

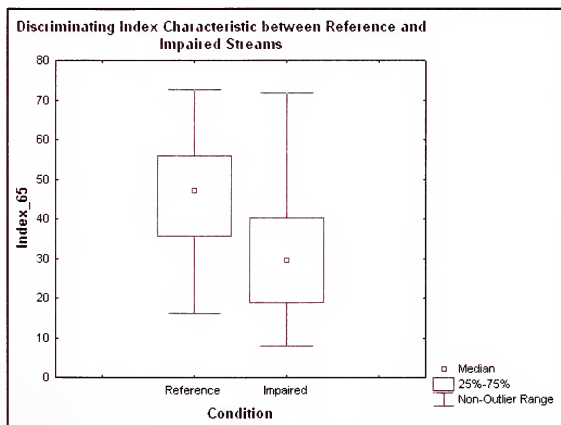


Table 28. Description of Numeric Ranking for Ecoregion 65. n=all reference and impaired sites in ecoregion 65.

Index Score	Numeric Ranking	Percentile n= 103
63 and above	1	Above 95th
49-62	2	Below 95 th , Above 75th
23-48	3	Below 75 th , Above 25th
16-22	4	Below 25 th , Above 5th
15 and below	5	Below 5th

Table 29. Stream Rating for Ecoregion 65.

Stream	StationID	Subcoregion	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Pine Knot Creek	HH25	65c	Reference	73	1	very good	A
Deep Creek	65c-40	65c	Impaired	72	1	very good	A
Hannahatchee Creek	65d-14	65d	Reference	71	1	very good	A
Magtail Branch	65c-12	65c	Impaired	65	1	very good	A
Cedar Creek	65k-55	65k	Reference	64	1	very good	A
Roaring Branch	65d-39	65d	Impaired	62	2	good	A
South Mosquito Creek	65h-212	65h	Reference	62	2	good	A
Bay Branch	65l-146	65l	Impaired	62	2	good	A
Bear Creek	65k-127	65k	Impaired	60	2	good	A
Coheelee Creek	HH29	65g	Reference	59	2	good	A
Shaw Creek	65h-206	65h	Reference	58	2	good	A
Shoal Creek	HH26	65c	Reference	58	2	good	A
Clyatt Mill Creek	65o-23	65o	Reference	56	2	good	A
Grass Creek	65d-18	65d	Reference	56	2	good	A
Whitewater Creek	HH24	65c	Reference	55	2	good	A
Olive Creek	65o-3	65o	Impaired	55	2	good	A
Sweetwater Creek	65c-8	65c	Impaired	54	2	good	A
Hollis Creek	65c-89	65c	Reference	53	2	good	A
Callahan Branch	65h-202	65h	Reference	53	2	good	A
Sally Branch	65d-4	65d	Reference	53	2	good	A
Clear Creek	65d-21	65d	Impaired	52	2	good	A
Trib Chickasawatchee Creek	65g-83	65g	Ref/Removed	52	2	good	A
Talipahoga Run Creek	65d-17	65d	Impaired	51	2	good	A
Lanahasssee Creek	65c-80	65c	Reference	51	2	good	A
Sugar Creek	65h-174	65h	Impaired	50	2	good	A
Sand Creek	65h-37	65h	Impaired	48	3	fair	B
Redland Creek	65o-24	65o	Reference	48	3	fair	B
Day Creek	65d-20	65d	Impaired	47	3	fair	B

Table 29. Stream Rating for Ecoregion 65 (cont.).

Mill Creek	65l-10	65l	Reference	47	3	fair	B
Fourmile Creek	65h-203	65h	Reference	47	3	fair	B
Angelica Creek	65k-115	65k	Impaired	46	3	fair	B
Horsehead Creek	65k-102	65k	Impaired	46	3	fair	B
Spring Hill Creek	65k-100	65k	Impaired	46	3	fair	B
Wolf Creek	65h-14	65h	Impaired	45	3	fair	B
Hadley Creek	65o-12	65o	Reference	45	3	fair	B
Hollaca Creek	65d-3	65d	Reference	44	3	fair	B
Maiden Creek	65k-54	65k	Reference	43	3	fair	B
Porter Creek	65k-56	65k	Reference	43	3	fair	B
Waukeefriskee Creek	65d-38	65d	Reference	42	3	fair	B
Butler Creek	65c-5	65c	Impaired	41	3	fair	B
Rae's Creek	65c-3	65c	Impaired	40	3	fair	B
Warrior Creek	65h-41	65h	Impaired	40	3	fair	B
Trib to Kinchafoonee Creek	65k-129	65k	Impaired	40	3	fair	B
Long Branch	65k-128	65k	Impaired	40	3	fair	B
Trib to Flint River	65g-69	65g	Impaired	38	3	fair	B
Hitchitee Creek	65c-88	65c	Impaired	38	3	fair	B
Drag Nasty Creek	65d-32	65d	Impaired	36	3	fair	B
Gully Creek	65g-17	65g	Impaired	36	3	fair	B
Little Sturgeon Creek	65l-381	65l	Reference	36	3	fair	B
Trib to New River	65o-25	65o	Reference	35	3	fair	B
Alagood Creek	65o-18	65o	Impaired	35	3	fair	B
Big Cedar Creek	65k-37	65k	Impaired	34	3	fair	B
Camp Creek	65l-234	65l	Impaired	34	3	fair	B
Crooked Creek	65k-68	65k	Reference	34	3	fair	B
Odum Creek	65g-120	65g	Reference	32	3	fair	B
Gum Branch	65c-38	65c	Impaired	32	3	fair	B
Rocky Creek	65c-4	65c	Impaired	32	3	fair	B
Stitchhatchie Creek	65l-184	65l	Impaired	32	3	fair	B

Table 29. Stream Rating for Ecoregion 65 (cont.).

Trib to Willacoochee Creek	65h-209	65h	Reference	32	3	fair	B
Clear Creek	65c-92	65c	Impaired	32	3	fair	B
Beaver Creek	65c-48	65c	Impaired	31	3	fair	B
Trib to Withlacoochee	65o-22	65o	Impaired	30	3	fair	B
Hat Creek	65h-24	65h	Impaired	30	3	fair	B
Trib to West Fork Deep Creek	65h-17	65h	Impaired	29	3	fair	B
Opposum Creek	65l-342	65l	Reference	28	3	fair	B
Pine Creek	65o-11	65o	Impaired	28	3	fair	B
Trib to Canoochee River	65l-160	65l	Impaired	28	3	fair	B
Mill Branch	65l-420	65l	Impaired	27	3	fair	B
Town Creek	65k-113	65k	Impaired	26	3	fair	B
Weracoba Creek	65d-1	65d	Impaired	25	3	fair	B
Fishing Creek	65l-343	65l	Reference	25	3	fair	B
Pataula Creek	65d-22	65d	Impaired	25	3	fair	B
McQuaddy Branch	65k-18	65k	Impaired	25	3	fair	B
Trib to Dry Creek	65g-130	65g	Impaired	23	3	fair	B
Parker's Mill Creek	65k-110	65k	Impaired	23	3	fair	B
Trib to Alapaha River	65h-1	65h	Impaired	23	3	fair	B
Trib to Gum Creek	65g-10	65g	Impaired	22	4	poor	C
Vicker's Stream	65l-423	65l	Impaired	22	4	poor	C
Trib to Sandy Mount	65l-281	65l	Impaired	21	4	poor	C
Trib to Big Indian Creek	65k-99	65k	Impaired	21	4	poor	C
Trib to Gum Creek	65g-14	65g	Impaired	20	4	poor	C
Red Bluff Creek	65l-379	65l	Reference	19	4	poor	C
Little Sturgeon Creek	65l-391	65l	Impaired	19	4	poor	C
Pennahatchee Creek	65l-280	65l	Impaired	19	4	poor	C
Little Creek	65l-235	65l	Impaired	19	4	poor	C
Trib to Little Pennahatchee Creek	65l-283	65l	Impaired	18	4	poor	C
Deep Creek	65h-4	65h	Impaired	18	4	poor	C

Table 29. Stream Rating for Ecoregion 65 (cont.).

Brushy Creek	65l-390	65l	Impaired	18	4	poor	C
Fish Pond Drain	65g-135	65g	Impaired	17	4	poor	C
Trib to Fish Pond Drain	65g-137	65g	Impaired	17	4	poor	C
Okeetuck Creek	65k-85	65k	Reference	16	4	poor	C
Lime Sink Creek	65h-34	65h	Impaired	16	4	poor	C
Snapping Creek	65h-13	65h	Impaired	16	4	poor	C
Red Oak Creek	65h-5	65h	Impaired	16	4	poor	C
Little Creek	65g-4	65g	Impaired	16	4	poor	C
Keel Creek	65g-82	65g	Ref/Removed	15	5	very poor	C
Reedy Creek	65l-403	65l	Impaired	15	5	very poor	C
Lilly River	65g-8	65g	Impaired	15	5	very poor	C
Daniels Creek	65h-32	65h	Impaired	14	5	very poor	C
Wildcat Creek	65l-277	65l	Impaired	12	5	very poor	C
Trib to Pachitta Creek	65g-84	65g	Impaired	11	5	very poor	C
Connell Creek	65o-9	65o	Impaired	8	5	very poor	C

Figure 28. 65c – Sand Hills.

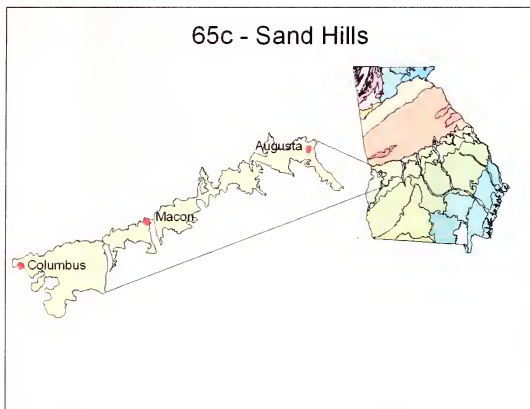


Figure 29. Typical Reference Stream – Subcoregion 65c.



Figure 30. Typical Impaired Stream – Subcoregion 65c.



Table 30. Index 65c.

Metric	Metric Category
% Tricoptera	Composition
Tolerant Taxa	Tolerance
Intolerant Taxa	
% Scraper	Functional Feeding Group
Clinger Taxa	Habitat

Table 31. Descriptive Statistics for Reference Streams in Subcoregion 65c. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 5					Maximum
			5th	25th	50th	75th	95th	
% Tricoptera	0.7	4.3	4.5	5.1	8.8	13.7	23.8	26.3
Tolerant Taxa	0.8	3.0	3.8	7.0	10.0	11.0	11.8	12.0
Intolerant Taxa	0.8	3.0	3.4	5.0	5.0	9.0	10.6	11.0
% Scraper	0.9	4.0	5.0	10.8	11.3	23.6	27.1	28.0
Clinger Taxa	0.6	10.0	10.2	11.0	12.0	15.0	16.6	17.0

Figure 31. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 65c.

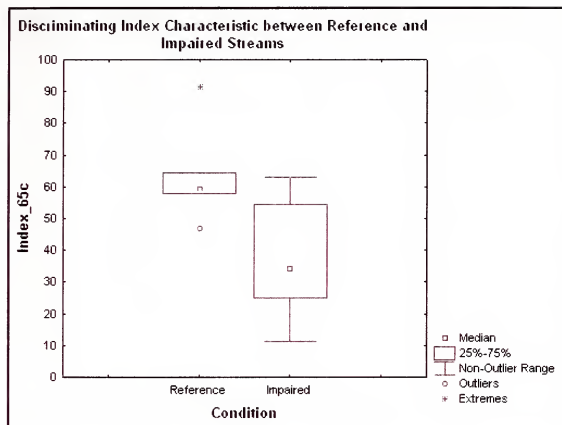


Table 32. Description of Numeric Ranking for Subcoregion 65c. n=all reference and impaired sites in subcoregion 65c.

Index Score	Numeric Ranking	Percentile n = 15
73 and above	1	Above 95th
61-72	2	Below 95 th , Above 75th
30-60	3	Below 75 th , Above 25th
20-29	4	Below 25 th , Above 5th
19 and below	5	Below 5th

Table 33. Stream Rating for Subcoregion 65c.

Streams	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Pine Knot Creek	HH25	Reference	92	1	very good	A
Whitewater Creek	HH24	Reference	65	2	good	A
Deep Creek	65c-40	Impaired	63	2	good	A
Rae's Creek	65c-3	Impaired	62	2	good	A
Lanahassee Creek	65c-80	Reference	59	3	fair	B
Hollis Creek	65c-89	Reference	58	3	fair	B
Sweetwater Creek	65c-8	Impaired	55	3	fair	B
Magtail Branch	65c-12	Impaired	52	3	fair	B
Shoal Creek	HH26	Reference	47	3	fair	B
Hitchitee Creek	65c-88	Impaired	35	3	fair	B
Butler Creek	65c-5	Impaired	34	3	fair	B
Gum Branch	65c-38	Impaired	26	4	poor	C
Clear Creek	65c-92	Impaired	25	4	poor	C
Beaver Creek	65c-48	Impaired	24	4	poor	C
Rocky Creek	65c-4	Impaired	11	5	very poor	C

Figure 32. 65d – Southern Hilly Gulf Coastal Plain.

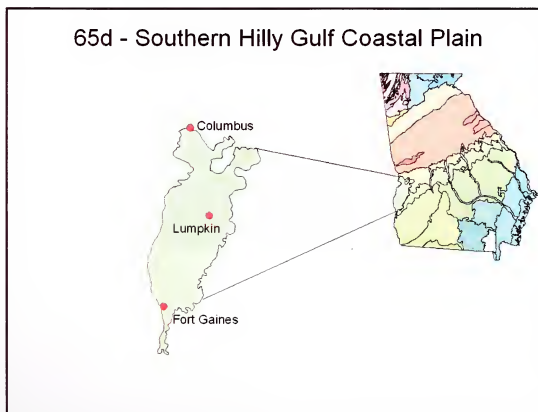


Figure 33. Typical Reference Stream – Subecoregion 65d.

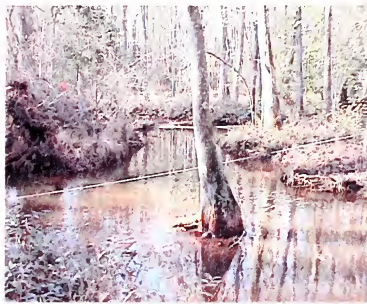


Figure 34. Typical Impaired Stream – Subecoregion 65d.



Table 34. Index 65d.

Metric	Metric Category
Plecoptera Taxa	Richness
% Chironomidae	Composition
% Hydropsychidae/ EPT	
% Filterer	Functional Feeding Group
Swimmer Taxa	Habitat

Table 35. Descriptive Statistics for Reference Streams in Subcoregion 65d. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 5					Maximum
			5th	25th	50th	75th	95th	
Plecoptera Taxa	0.7	0.0	0.6	3.0	3.0	3.0	5.4	6.0
% Chironomidae	0.7	34.1	36.0	43.8	45.2	53.3	67.3	70.8
% Hydropsychidae/ EPT	0.6	0.0	0.9	4.4	8.7	9.1	15.0	16.5
% Filterer	0.7	0.4	1.3	4.7	5.4	7.9	8.2	8.3
Swimmer Taxa	0.6	1.0	1.0	1.0	2.0	2.0	2.8	3.0

Figure 35. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 65d.

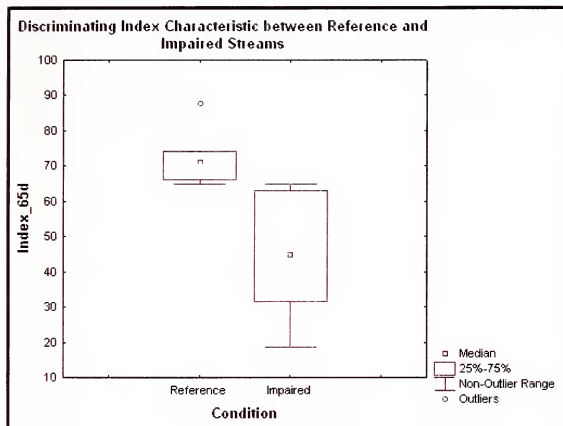


Table 36. Description of Numeric Ranking for Subcoregion 65d. n=all reference and impaired sites in subcoregion 65d.

Index Score	Numeric Ranking	Percentile n= 12
81 and above	1	Above 95th
68-80	2	Below 95 th , Above 75th
45-67	3	Below 75 th , Above 25th
27-44	4	Below 25 th , Above 5th
26 and below	5	Below 5th

Table 37. Stream Rating for Subcoregion 65d.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Hannahatchee Creek	65d-14	Reference	88	1	very good	A
Sally Branch	65d-4	Reference	74	2	good	A
Hollaca Creek	65d-3	Reference	71	2	good	A
Grass Creek	65d-18	Reference	66	3	fair	B
Clear Creek	65d-21	Impaired	65	3	fair	B
Waukeefriskee Creek	65d-38	Reference	65	3	fair	B
Roaring Branch	65d-39	Impaired	63	3	fair	B
Day Creek	65d-20	Impaired	50	3	fair	B
Drag Nasty Creek	65d-32	Impaired	45	3	fair	B
Talipahoga Rum Creek	65d-17	Impaired	40	4	poor	C
Pataula Creek	65d-22	Impaired	31	4	poor	C
Weracoba Creek	65d-1	Impaired	19	5	very poor	C

Figure 36. 65g – Dougherty Plain.

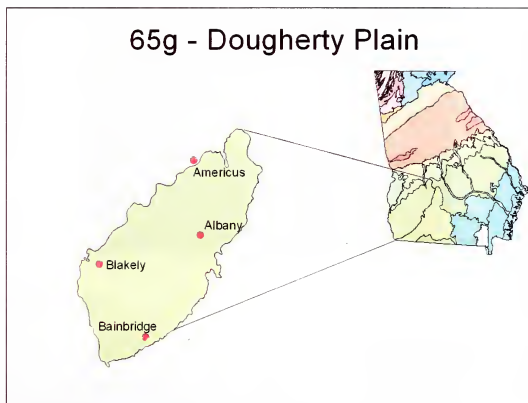


Figure 37. Typical Reference Stream – Subcoregion 65g.



Figure 38. Typical Impaired Stream – Subcoregion 65g.



Table 38. Index 65g.

Metric	Metric Category
EPT Taxa	Richness
% Oligochaeta	Composition
% Intolerant Individuals	
HBI	Functional Feeding Group
Filterer Taxa	
Clinger Taxa	Habitat

Table 39. Descriptive Statistics for Reference Streams in Subcoregion 65g. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 3					Maximum
			5th	25th	50th	75th	95th	
EPT Taxa	1.0	7.0	7.0	7.0	7.0	11.5	15.1	16.0
% Oligochaeta	1.0	1.4	1.5	2.0	2.5	2.7	2.9	2.9
% Intolerant Individuals	1.0	3.0	3.0	3.0	3.0	5.0	6.6	7.0
HBI	1.0	4.9	5.0	5.2	5.5	5.7	5.9	6.0
Filterer Taxa	0.8	3.0	3.1	3.5	4.0	5.5	6.7	7.0
Clinger Taxa	1.0	6.0	6.2	7.0	8.0	9.0	9.8	10.0

Figure 39. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 65g.

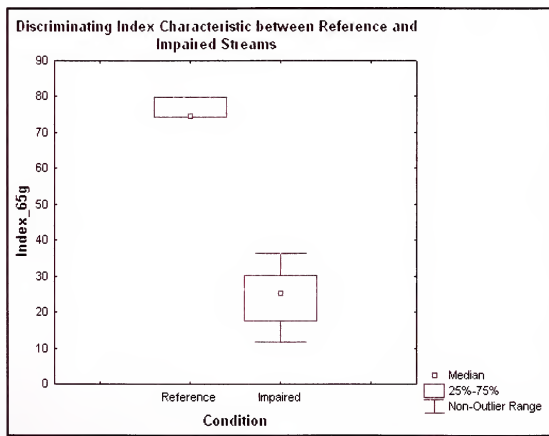


Table 40. Description of Numeric Ranking for Subcoregion 65g. n=all reference and impaired sites in Subcoregion 65g.

Index Score	Numeric Ranking	Percentile n = 15
76 and above	1	Above 95th
48-75	2	Below 95 th , Above 75th
24-47	3	Below 75 th , Above 25th
14-23	4	Below 25 th , Above 5th
13 and below	5	Below 5th

Table 41. Stream Rating for Subcoregion 65g.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Coheelee Creek	HH29	Reference	80	1	very good	A
Odom Creek	65g-120	Reference	74	2	good	A
Kiokee Creek	65g-62	Reference	74	2	good	A
Trib Chickasawhatchee Creek	65g-83	Ref/Removed	60	2	good	A
Trib to Flint River	65g-69	Impaired	36	3	fair	B
Trib to Dry Creek	65g-130	Impaired	33	3	fair	B
Gully Creek	65g-17	Impaired	30	3	fair	B
Keel Creek	65g-82	Ref/Removed	30	3	fair	B
Trib to Fish Pond Drain	65g-137	Impaired	28	3	fair	B
Trib to Gum Creek	65g-10	Impaired	27	3	fair	B
Little Creek	65g-4	Impaired	24	3	fair	B
Lilly River	65g-8	Impaired	24	3	fair	B
Fish Pond Drain	65g-135	Impaired	17	4	poor	C
Trib to Gum Creek	65g-14	Impaired	15	4	poor	C
Trib to Pachitta Creek	65g-84	Impaired	12	5	very poor	C

Figure 40. 65h – Tifton Upland.

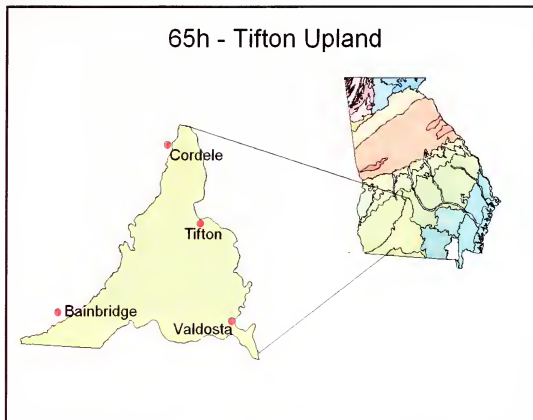


Figure 41. Typical Reference Stream – Subcoregion 65h.



Figure 42. Typical Impaired Stream – Subcoregion 65h.



Table 42. Index 65h.

Metric	Metric Category
Tanytarsini Taxa	Richness
Shannon-Wiener base e	
% Oligochaeta	Composition
% Tanytarsini	
NCBI	Tolerance
% Predator	Functional Feeding Group
Clinger Taxa	Habitat

Table 43. Descriptive Statistics for Reference Streams in Subcoregion 65h. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 5					Maximum
			5th	25th	50th	75th	95th	
Tanytarsini Taxa	0.8	2.0	2.6	5.0	5.0	8.0	11.2	12.0
Shannon- Wiener base e	0.7	2.6	2.7	2.8	3.0	3.0	3.3	3.4
% Oligochaeta	0.9	4.9	4.9	5.1	5.7	6.7	7.2	7.3
% Tanytarsini	1.0	8.2	9.3	13.6	15.4	38.3	42.9	44.1
NCBI	0.8	4.9	4.9	5.1	5.7	6.7	7.2	7.3
% Predator	0.6	7.9	8.1	9.0	13.2	14.1	22.7	24.9
Clinger Taxa	0.9	4.0	4.4	6.0	7.0	10.0	11.6	12.0

Figure 43. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 65h.

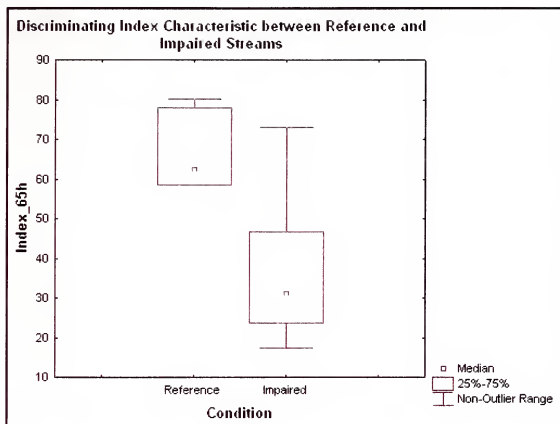


Table 44. Description of Numeric Ranking for Subcoregion 65h. n=all reference and impaired sites in subcoregion 65h.

Index Score	Numeric Ranking	Percentile n = 17
79 and above	1	Above 95th
59-78	2	Below 95 th , Above 75th
26-58	3	Below 75 th , Above 25th
19-25	4	Below 25 th , Above 5th
18 and below	5	Below 5th

Table 45. Stream Rating for Subcoregion 65h.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Fourmile Creek	65h-203	Reference	80	1	very good	A
South Mosquito Creek	65h-212	Reference	78	2	good	A
Sugar Creek	65h-174	Impaired	73	2	good	A
Callahan Branch	65h-202	Reference	62	2	good	A
Trib to Willacoochee Creek	65h-209	Reference	58	3	fair	B
Shaw Creek	65h-206	Reference	58	3	fair	B
Sand Creek	65h-37	Impaired	52	3	fair	B
Hat Creek	65h-24	Impaired	49	3	fair	B
Wolf Creek	65h-14	Impaired	44	3	fair	B
Warrior Creek	65h-41	Impaired	44	3	fair	B
Trib to West Fork Deep Creek	65h-17	Impaired	34	3	fair	B
Deep Creek	65h-4	Impaired	28	3	fair	B
Trib to Alapaha River	65h-1	Impaired	26	3	fair	B
Snapfinger Creek	65h-13	Impaired	24	4	poor	C
Red Oak Creek	65h-5	Impaired	23	4	poor	C
Daniels Creek	65h-32	Impaired	19	4	poor	C
Lime Sink Creek	65h-34	Impaired	17	5	very poor	C

Figure 44. 65k Coastal Plain Red Uplands.

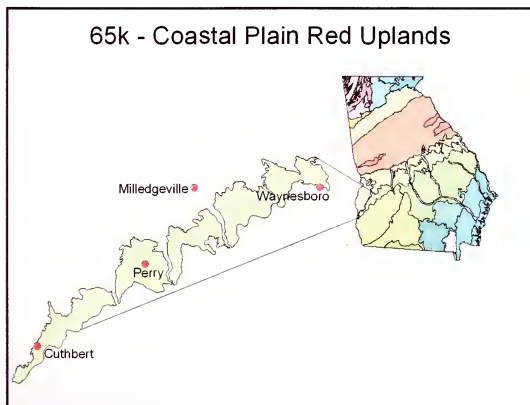


Figure 45. Typical Reference Stream – Subcoregion 65k.



Figure 46. Typical Impaired Stream – Subcoregion 65k.



Table 46. Index 65k.

Metric	Metric Category
% Gastropoda	Composition
% Orthocladinae/Total Chironomidae	
% Coleoptera	
% Hydropsychidae/Total Trichoptera	
% Filterer	Functional Feeding Group
% Collector	

Table 47. Descriptive Statistics for Reference Streams in Subcoregion 65k. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 5					Maximum
			5th	25th	50th	75th	95th	
% Gastropoda	0.8	1.0	1.0	1.2	1.7	2.0	2.5	2.6
% Orthocladinae/Total Chironomidae	0.6	0.8	2.2	7.6	25.3	94.5	98.9	100.0
% Coleoptera	0.6	1.2	5.9	11.3	12.1	16.4	9.4	17.5
% Hydropsychidae/Total Trichoptera	0.6	0.0	0.0	0.0	0.0	25.0	85.0	100.0
% Filterer	0.6	0.5	1.1	3.6	5.1	10.4	20.8	23.4
% Collector	0.9	27.8	31.6	46.8	51.2	76.3	92.0	96.0

Figure 47. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 65k.

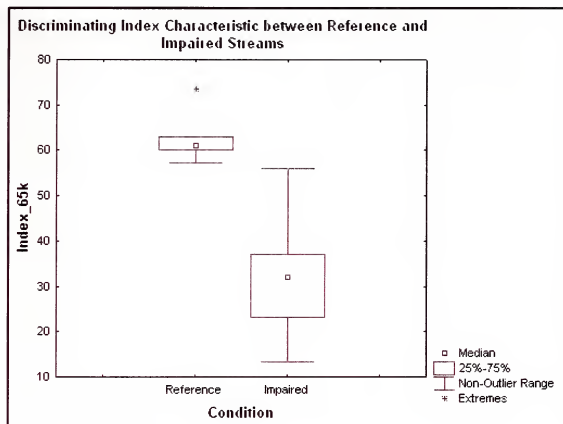


Table 48. Description of Numeric Ranking for Subcoregion 65k. n=all reference and impaired sites in subcoregion 65h.

Index Score	Numeric Ranking	Percentile n = 16
66 and above	1	Above 95th
58-65	2	Below 95 th , Above 75th
27-57	3	Below 75 th , Above 25th
16-26	4	Below 25 th , Above 5th
15 and below	5	Below 5th

Table 49. Stream Rating for Subcoregion 65k.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
McQuaddy Branch	65k-85	Reference	74	1	very good	A
Spring Hill Creek	65k-54	Reference	63	2	good	A
Parker's Mill Creek	65k-55	Reference	61	2	good	A
Angelica Creek	65k-56	Reference	60	2	good	A
Bear Creek	65k-68	Reference	57	3	fair	B
Long Branch	65k-129	Impaired	56	3	fair	B
Big Cedar Creek	65k-37	Impaired	56	3	fair	B
Trib to Kinchafoonee Creek	65k-18	Impaired	37	3	fair	B
Town Creek	65k-128	Impaired	37	3	fair	B
Trib to Big Indian Creek	65k-99	Impaired	34	3	fair	B
Okeetuck Creek	65k-115	Impaired	32	3	fair	B
Maiden Creek	65k-100	Impaired	28	3	fair	B
Cedar Creek	65k-102	Impaired	25	4	poor	C
Crooked Creek	65k-113	Impaired	23	4	poor	C
Porter Creek	65k-110	Impaired	16	4	poor	C
Horsehead Creek	65k-127	Impaired	13	5	very poor	C

Figure 48. 65I – Atlantic Southern Loam Plains (Vidalia Uplands).

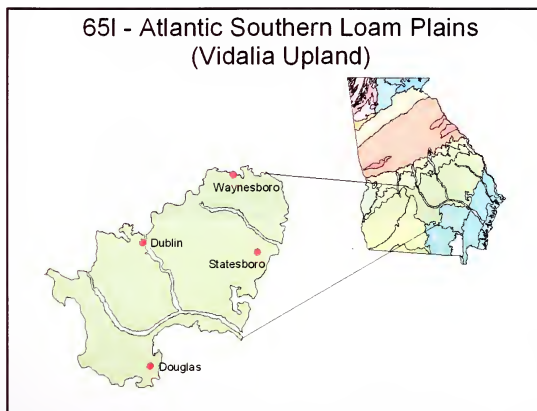


Figure 49. Typical Reference Stream – Subecoregion 65I.



Figure 50. Typical Impaired Stream – Subecoregion 65I.



Table 50. Index 65I.

Metric	Metric Category
EPT Taxa	Richness
Diptera Taxa	
% EPT	Composition
% Trichoptera	
HBI	Tolerance
Predator Taxa	Functional Feeding Group
Clinger Taxa	Habitat

Table 51. Descriptive Statistics for Reference Streams in Subecoregion 65I. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 5					Maximum
			5th	25th	50th	75th	95th	
EPT Taxa	0.8	0.0	0.6	3.0	5.0	7.0	7.8	8.0
Diptera Taxa	0.6	13.0	15.4	25.0	26.0	32.0	33.6	34.0
% EPT	0.8	0.0	0.3	1.3	4.6	7.5	8.5	8.8
% Trichoptera	0.9	0.0	0.3	1.3	2.1	2.5	4.0	4.4
HBI	0.6	5.2	5.2	5.3	6.4	7.0	7.4	7.5
Predator Taxa	0.7	3.0	3.8	7.0	8.0	8.0	10.4	11.0
Clinger Taxa	0.8	1.0	1.6	4.0	5.0	8.0	11.2	12.0

Figure 51. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 65I.

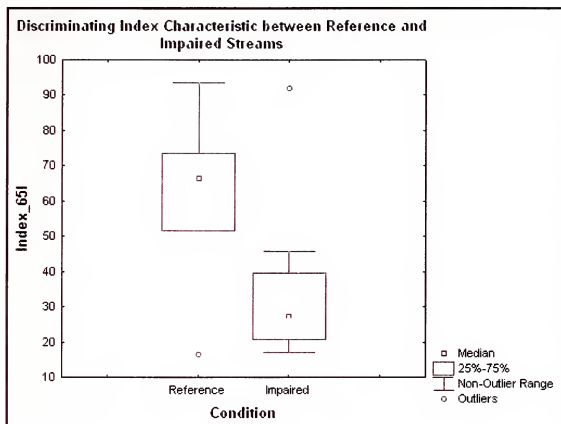


Table 52. Description of Numeric Ranking for Subcoregion 65I. n=all reference and impaired sites in subcoregion 65I.

Index Score	Numeric Ranking	Percentile n = 19
92 and above	1	Above 95 th
49-91	2	Below 95 th , Above 75 th
23-48	3	Below 75 th , Above 25 th
18-22	4	Below 25 th , Above 5 th
17 and below	5	Below 5 th

Table 53. Stream Rating for Subcoregion 65I.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Mill Creek	65I-10	Reference	94	1	very good	A
Bay Branch	65I-146	Impaired	92	1	very good	A
Little Sturgeon Creek	65I-381	Reference	74	2	good	A
Fishing Creek	65I-343	Reference	66	2	good	A
Opposum Creek	65I-342	Reference	52	2	good	A
Stitchihatchie Creek	65L-184	Impaired	46	3	fair	B
Trib to Canoochee River	65I-160	Impaired	45	3	fair	B
Mill Branch	65I-420	Impaired	40	3	fair	B
Pennahatchee Creek	65I-280	Impaired	32	3	fair	B
Trib to Sandy Mount	65I-281	Impaired	30	3	fair	B
Little Sturgeon Creek	65I-391	Impaired	28	3	fair	B
Vicker's Stream	65I-423	Impaired	27	3	fair	B
Brushy Creek	65I-390	Impaired	25	3	fair	B
Wildcat Creek	65I-277	Impaired	23	3	fair	B
Trib to Little Pennehatchee Creek	65I-283	Impaired	21	4	poor	C
Little Creek	65I-235	Impaired	20	4	poor	C
Reedy Creek	65I-403	Impaired	20	4	poor	C
Camp Creek	65I-234	Impaired	17	5	very poor	C
Red Bluff Creek	65I-379	Reference	16	5	very poor	C

Figure 52. 65o – Tallahassee Hills/Valdosta Limesink.

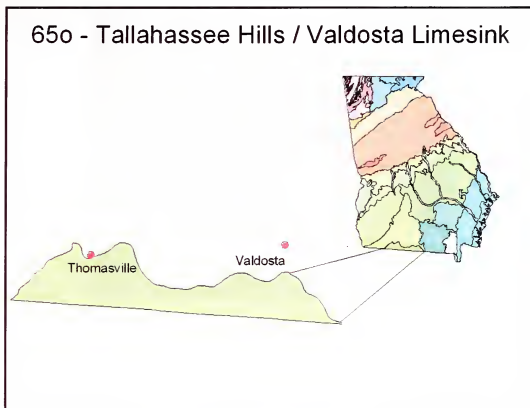


Figure 53. Typical Reference Stream – Subcoregion 65o.



Figure 54. Typical Impaired Stream – Subecoregion 65o.



Table 54. Index 65o.

Metric	Metric Category
Chironomidae Taxa	Richness
% Oligochaeta	Composition
Beck's Index	Tolerance
NCBI	
Scraper Taxa	Functional Feeding Group
Burrower Taxa	Habitat
Sprawler Taxa	

Table 55. Descriptive Statistics for Reference Streams in Subcoregion 65o. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 4					Maximum
			5th	25th	50th	75th	95th	
Chironomidae Taxa	0.8	13.0	14.2	19.0	25.5	32.3	37.7	39.0
% Oligochaeta	0.8	0.0	0.0	0.0	1.9	3.9	4.3	4.4
Beck's Index	0.4	2.0	2.5	4.3	5.0	6.8	11.0	12.0
NCBI	0.6	5.3	5.4	5.5	6.0	6.9	8.0	8.2
Scraper Taxa	0.8	1.0	1.3	2.5	3.0	3.0	3.0	3.0
Burrower Taxa	0.6	3.0	3.5	5.3	6.0	8.8	15.4	17.0
Sprawler Taxa	0.8	3.0	3.9	7.5	9.0	9.0	9.0	9.0

Figure 55. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 65o.

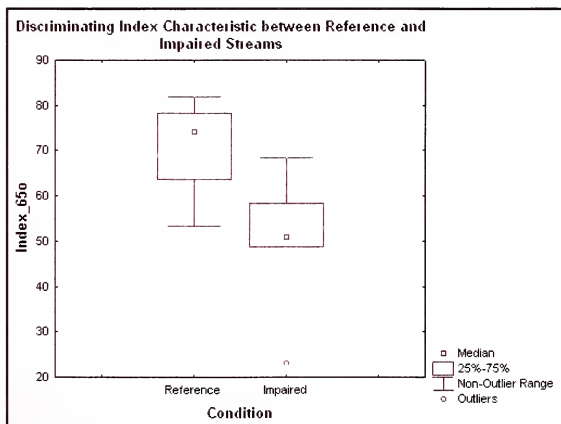


Table 56. Description of Numeric Ranking for Subcoregion 65o. n=all reference and impaired sites in subcoregion 65o.

Index Score	Numeric Ranking	Percentile n = 9
79 and above	1	Above 95th
74-78	2	Below 95 th , Above 75th
51-73	3	Below 75 th , Above 25th
33-50	4	Below 25 th , Above 5th
32 and below	5	Below 5th

Table 57. Stream Rating for Subcoregion 65o.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Clyatt Mill Creek	65o-23	Reference	82	1	very good	A
Redland Creek	65o-24	Reference	74	2	good	A
Hadley Creek	65o-12	Reference	74	2	good	A
Olive Creek	65o-3	Impaired	69	3	fair	B
Trib to Withlacoochee	65o-22	Impaired	58	3	fair	B
Trib to New River	65o-25	Reference	53	3	fair	B
Pine Creek	65o-11	Impaired	51	3	fair	B
Alagood Creek	65o-18	Impaired	49	4	poor	C
Connell Creek	65o-9	Impaired	23	5	very poor	C

Figure 56. Ecoregion 66 – Blue Ridge.

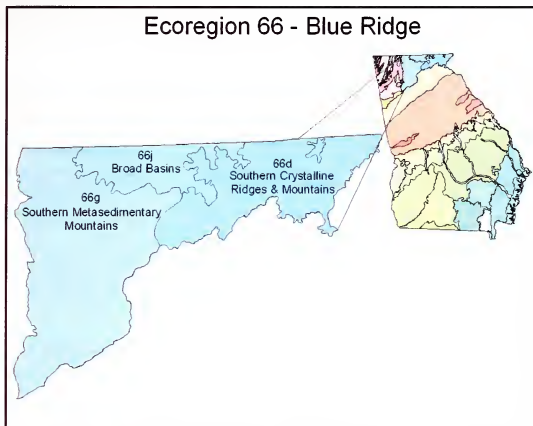


Table 58. Index 66.

Metric	Metric Category
Plecoptera Taxa	Richness
Simpson's Index	
% Trichoptera	
% Intolerant Individuals	Composition
NCBI	Tolerance
Predator Taxa	Functional Feeding Group
Burrower Taxa	Habitat

Table 59. Descriptive Statistics for Reference Streams in Ecoregion 66. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 15					Maximum
			5th	25th	50th	75th	95th	
Plecoptera Taxa	0.7	3.0	3.0	5.5	9.0	10.0	11.3	12.0
Simpson's Index	0.6	0.0	0.0	0.0	0.0	0.0	0.1	0.1
% Trichoptera	0.5	9.6	13.4	17.5	20.0	21.1	26.3	26.3
% Intolerant Individuals	0.6	12.5	18.5	24.6	37.9	48.3	52.0	54.7
NCBI	0.7	3.3	3.4	3.6	4.2	4.6	5.2	5.5
Predator Taxa	0.8	8.0	8.0	11.5	13.0	16.0	17.6	19.0
Burrower Taxa	0.5	4.0	4.7	6.0	7.0	8.5	9.6	11.0

Figure 57. Discriminating Index Characteristic between Reference and Impaired Streams for Ecoregion 66.

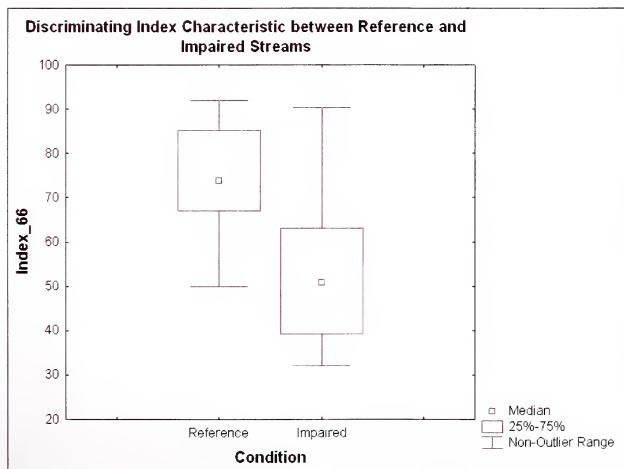


Table 60. Description of Numeric Ranking for Ecoregion 66. n=all reference and impaired sites in ecoregion 66.

Index Score	Numeric Ranking	Percentile n = 32
90 and above	1	Above 95th
76-89	2	Below 95 th , Above 75th
49-75	3	Below 75 th , Above 25th
34-48	4	Below 25 th , Above 5th
33 and below	5	Below 5th

Table 61. Stream Rating for Ecoregion 66.

Stream	StationID	Subcoregion	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Nimblewill Creek	66g-23	66g	Reference	92	1	very good	A
Clear Creek	66d-48	66d	Impaired	90	1	very good	A
Chattahoochee River	66d-40	66d	Reference	90	1	very good	A
Dukes Creek	66d-41	66d	Reference	88	2	good	A
Mill Creek	66g-5	66g	Reference	85	2	good	A
Rough Creek	66g-2-2	66g	Reference	80	2	good	A
West Fork Wolf Creek	66d-38	66d	Impaired	80	2	good	A
Moccasin Creek	66j-23	66j	Reference	77	2	good	A
Coleman River	66d-44-2	66d	Reference	75	3	fair	B
South Fork Rappier Mill Creek	66j-28	66j	Reference	74	3	fair	B
Trib to Talking Rock Creek	66g-42	66g	Impaired	74	3	fair	B
Bryan Creek	66j-211	66j	Reference	72	3	fair	B
Tallulah River	66d-44	66d	Reference	70	3	fair	B
Wolf Creek	66j-26	66j	Impaired	68	3	fair	B
Hothouse Creek	66j-19	66j	Reference	67	3	fair	B
Holly Creek	66g-6	66g	Reference	67	3	fair	B
Young Cane Creek	66j-27	66j	Impaired	63	3	fair	B
East Gumlog Creek	66j-31	66j	Reference	58	3	fair	B
Yellow Creek	66g-71	66g	Impaired	56	3	fair	B
Tiger Creek	66d-49	66d	Impaired	55	3	fair	B
Town Creek	66d-58	66d	Reference	55	3	fair	B
Sugar Creek	66j-9	66j	Impaired	53	3	fair	B
Hightower Creek	66d-43	66d	Impaired	51	3	fair	B
Jacks River	66g-2	66g	Reference	50	3	fair	B
Flat Creek	66g-39	66g	Impaired	43	4	poor	C
Talking Rock Creek	66g-65	66g	Impaired	41	4	poor	C
Stekoa Creek	66d-50	66d	Impaired	39	4	poor	C

Table 61. Stream Rating for Ecoregion 66 (cont.).

Sharp Mountain Creek	66g-31	66g	Impaired	39	4	poor	C
Hempton Creek	66j-25	66j	Impaired	39	4	poor	C
Ivylog Creek	66j-17	66j	Impaired	33	5	very poor	C
Polecat Branch	66g-30	66g	Impaired	33	5	very poor	C
Little Scarecorn Creek	66g-44	66g	Impaired	32	5	very poor	C

Figure 58. 66d - Southern Crystalline Ridges & Mountains.

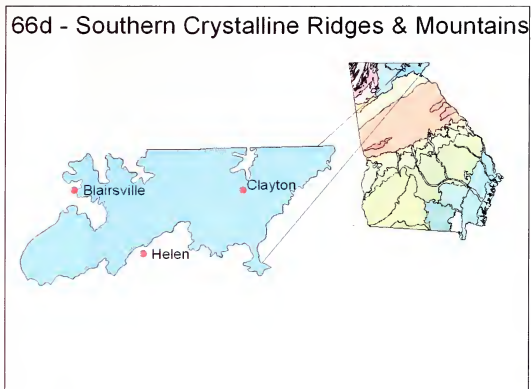


Figure 59. Typical Reference Stream – Subcoregion 66d.

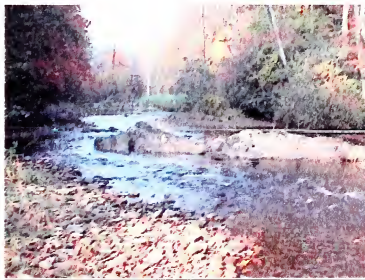


Figure 60. Typical Impaired Stream – Subcoregion 66d.



Table 62. Index 66d.

Metric	Metric Category
Diptera Taxa	Richness
% Plecoptera	Composition
% Odonata	
% Dominant Individuals	Tolerance
% Shredder	Functional Feeding Group
Clinger Taxa	Habitat

Table 63. Descriptive Statistics for Reference Streams in Subcoregion 66d. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 5					Maximum
			5th	25th	50th	75th	95th	
Diptera Taxa	0.8	16.0	17.4	23.0	25.0	26.0	30.0	31.0
% Plecoptera	0.6	11.3	12.1	15.4	24.7	30.4	30.8	30.8
% Odonata	1.0	0.0	0.0	0.0	0.4	0.8	3.8	4.5
% Dominant Individuals	0.6	7.9	8.2	9.1	11.3	12.5	15.2	15.8
% Shredder	0.8	8.3	9.5	14.1	14.2	32.1	33.5	33.9
Clinger Taxa	0.6	15.0	15.8	19.0	22.0	23.0	30.2	32.0

Figure 61. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 66d.

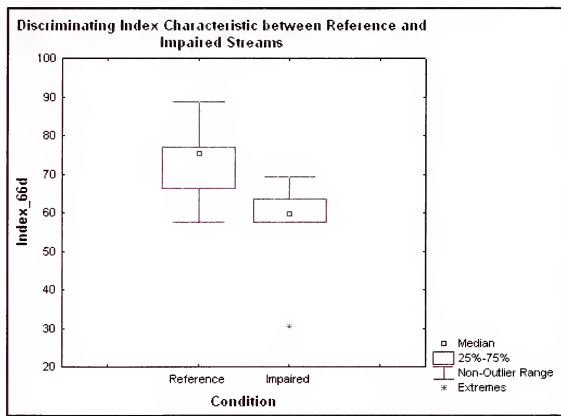


Table 64. Description of Numeric Ranking for Subcoregion 66d. n=all reference and impaired sites in Subcoregion 66d.

Index Score	Numeric Ranking	Percentile n = 10
83 and above	1	Above 95th
74-82	2	Below 95 th , Above 75th
58-73	3	Below 75 th , Above 25th
43-57	4	Below 25 th , Above 5th
42 and below	5	Below 5 th

Table 65. Stream Rating for Subcoregion 66d.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Tallulah River	66d-44	Reference	89	1	very good	A
Coleman River	66d-44-2	Reference	77	2	good	A
Chattahoochee River	66d-40	Reference	75	2	good	A
Hightower Creek	66d-43	Impaired	69	3	fair	B
Town Creek	66d-58	Reference	66	3	fair	B
Clear Creek	66d-48	Impaired	64	3	fair	B
Tiger Creek	66d-49	Impaired	60	3	fair	B
Dukes Creek	66d-41	Reference	58	3	fair	B
West Fork Wolf Creek	66d-38	Impaired	57	4	poor	C
Stekoa Creek	66d-50	Impaired	30	5	very poor	C

Figure 62. 66g – Southern Metasedimentary Mountains.

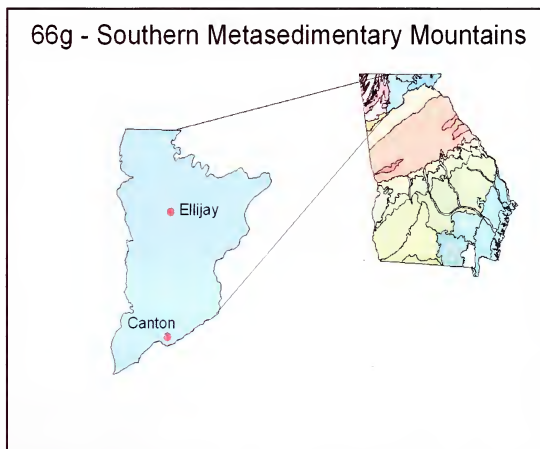


Figure 63. Typical Reference Stream – Subcoregion 66g



Figure 64. Typical Impaired Stream – Subcoregion 66g.



Table 66. Index 66g.

Metric	Metric Category
EPT Taxa	Richness
% Chironomidae	Composition
% Tanypodinae/Total Chironomidae	
NCBI	Tolerance
% Dominant Individuals	
Scraper Taxa	Functional Feeding Group
% Clinger	Habitat

Table 67. Descriptive Statistics for Reference Streams in Subcoregion 66g. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 5					Maximum
			5th	25th	50th	75th	95th	
EPT Taxa	0.9	11.0	14.2	27.0	27.0	35.0	36.6	37.0
% Chironomidae	0.9	3.6	5.5	13.2	22.5	23.8	24.0	24.0
% Tanypodinae/Total Chironomidae	0.9	0.0	0.4	1.9	7.1	7.1	8.4	8.8
NCBI	0.7	3.3	3.4	3.6	3.9	4.6	4.7	4.7
% Dominant Individuals	0.7	6.4	6.9	8.8	9.9	10.8	15.4	16.5
Scraper Taxa	0.9	3.0	3.6	6.0	7.0	8.0	9.6	10.0
% Clinger	0.7	26.4	30.5	46.7	52.4	57.5	75.4	79.9

Figure 65. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 66g.

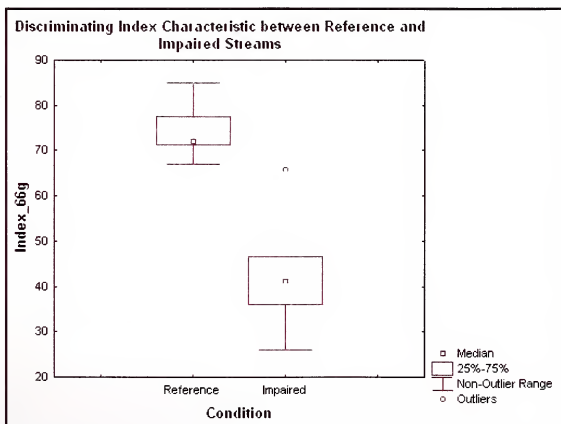


Table 68. Description of Numeric Ranking for Subcoregion 66g. n=all reference and impaired sites in Subcoregion 66g.

Index Score	Numeric Ranking	Percentile n = 12
81 and above	1	Above 95th
72-80	2	Below 95 th , Above 75th
40-71	3	Below 75 th , Above 25th
33-39	4	Below 25 th , Above 5th
32 and below	5	Below 5th

Table 69. Stream Rating for Subcoregion 66g.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Mill Creek	66g-5	Reference	85	1	very good	A
Nimblewill Creek	66g-23	Reference	78	2	good	A
Jacks River	66g-2	Reference	72	2	good	A
Holly Creek	66g-6	Reference	71	3	fair	B
Rough Creek	66g-2-2	Reference	67	3	fair	B
Trib to Talking Rock Creek	66g-42	Impaired	66	3	fair	B
Talking Rock Creek	66g-65	Impaired	47	3	fair	B
Yellow Creek	66g-71	Impaired	46	3	fair	B
Flat Creek	66g-39	Impaired	41	3	fair	B
Little Scarecorn Creek	66g-44	Impaired	39	4	poor	C
Sharp Mountain Creek	66g-31	Impaired	36	4	poor	C
Polecat Branch	66g-30	Impaired	26	5	very poor	C

Figure 66. 66j-Broad Basins.

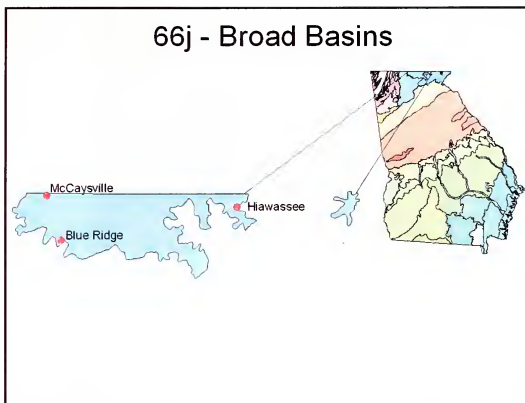


Figure 67. Typical Reference Stream – Subcoregion 66j.



Figure 68. Typical Impaired Stream – Subcoregion 66j.



Table 70. Index 66j.

Metric	Metric Category
Simpson's Diversity Index	Richness
Margalef's Index	
% Tanytarsini	Composition
% Intolerant Individuals	Tolerance
Predator Taxa	Functional Feeding Group
Sprawler Taxa	Habitat

Table 71. Descriptive Statistics for Reference Streams in Subcoregion 66j. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 5					Maximum
			5 th	25 th	50 th	75 th	95 th	
Simpson's Diversity Index	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Margalef's Index	0.8	11.5	11.5	11.6	12.4	13.0	13.5	13.7
% Tanytarsini	0.8	1.7	1.8	2.1	5.4	5.8	11.5	12.9
% Intolerant Individuals	0.6	24.6	24.6	24.6	34.6	37.9	41.3	42.1
Predator Taxa	0.8	8.0	8.6	11.0	12.0	14.0	15.6	16.0
Sprawler Taxa	0.6	13.0	13.4	15.0	18.0	20.0	21.6	22.0

Figure 69. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 66j.

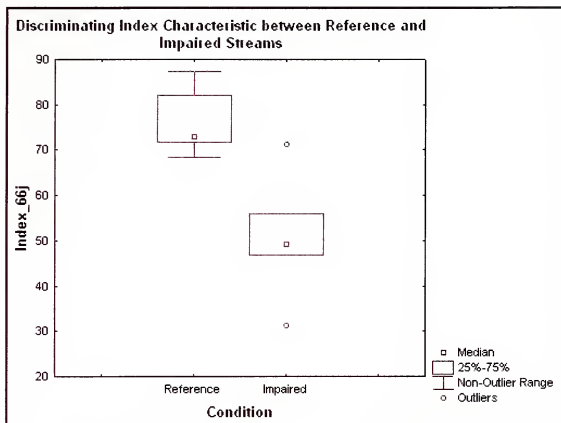


Table 72. Description of Numeric Ranking for Subcoregion 66j. n=all reference and impaired sites in Subcoregion 66j.

Index Score	Numeric Ranking	Percentile n = 10
85 and above	1	Above 95 th
73-84	2	Below 95 th , Above 75 th
51-72	3	Below 75 th , Above 25 th
38-50	4	Below 25 th , Above 5 th
37 and below	5	Below 5 th

Table 73. Stream Rating for Subecoregion 66j.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
South Fork Rapier Mill Creek	66j-28	Reference	87	1	very good	A
Bryan Creek	66j-211	Reference	82	2	good	A
East Gumlog Creek	66j-31	Reference	73	2	good	A
Moccasin Creek	66j-23	Reference	72	3	fair	B
Wolf Creek	66j-26	Impaired	71	3	fair	B
Hothouse Creek	66j-19	Reference	68	3	fair	B
Young Cane Creek	66j-27	Impaired	56	3	fair	B
Ivylog Creek	66j-17	Impaired	49	4	poor	C
Sugar Creek	66j-9	Impaired	47	4	poor	C
Hempton Creek	66j-25	Impaired	31	5	very poor	C

Figure 70. Ecoregion 67 – Ridge & Valley.

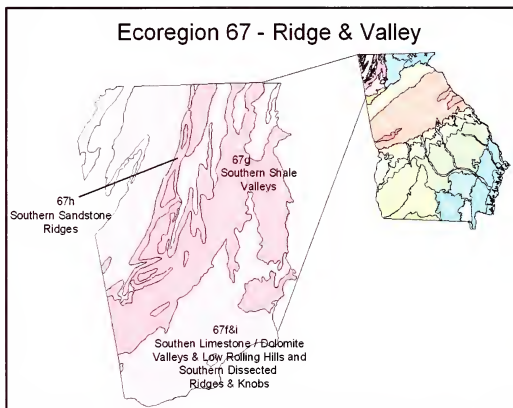


Table 74. Index 67.

Metric	Metric Category
EPT Taxa	Richness
Plecoptera Taxa	
% Plecoptera	Composition
% Isopoda	
HBI	Tolerance
Clinger Taxa	Habitat

Table 75. Descriptive Statistics for Reference Streams in Ecoregion 67. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 13					Maximum
			5th	25th	50th	75th	95th	
EPT Taxa	0.8	4.0	5.2	11.0	14.0	18.0	22.8	24.0
Plecoptera Taxa	0.8	0.0	0.0	3.0	3.0	6.0	6.8	8.0
% Plecoptera	0.8	0.0	0.0	1.7	4.0	10.4	19.9	31.7
% Isopoda	0.7	0.0	0.0	0.0	0.0	3.8	7.0	11.3
HBI	0.8	3.0	3.1	3.8	4.0	4.9	6.3	7.3
Clinger Taxa	0.7	5.0	7.4	14.0	14.0	17.0	22.8	24.0

Figure 71. Discriminating Index Characteristic between Reference and Impaired Streams for Ecoregion 67.

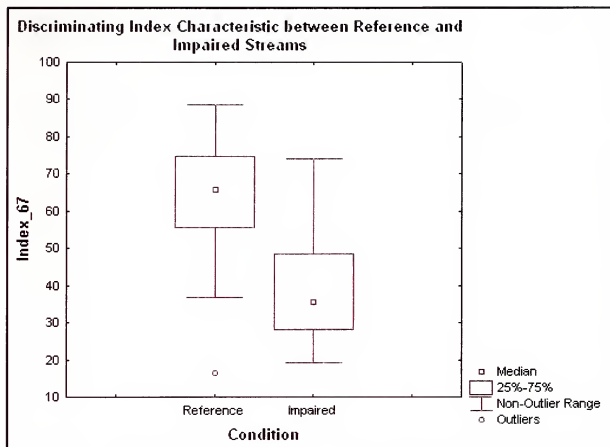


Table 76. Description of Numeric Ranking for Ecoregion 67. n=all reference and impaired sites in Ecoregion 67.

Index Score	Numeric Ranking	Percentile n = 26
77 and above	1	Above 95th
66-76	2	Below 95 th , Above 75 th
33-65	3	Below 75 th , Above 25 th
20-32	4	Below 25 th , Above 5 th
19 and below	5	Below 5 th

Table 77. Stream Rating for Ecoregion 67.

Stream	StationID	Subcoregion	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Kings Creek	67h-9	67h	Reference	89	1	very good	A
Cane Creek	67f&i-16	67f&i	Reference	78	1	very good	A
Snake Creek	67h-4	67h	Reference	76	2	good	A
Little Armuchee Creek	67g-11	67g	Reference	75	2	good	A
East Chicamagua Creek	67h-2	67h	Reference	74	2	good	A
Trib to Ruff Creek	67h-5	67h	Impaired	74	2	good	A
Moss Creek	67g-13	67g	Reference	66	2	good	A
Clarks Creek	67f&i-25	67f&i	Reference	66	2	good	A
Armuchee Creek	67f&i-17	67f&i	Reference	65	3	fair	B
Swamp Creek	67h-3	67h	Reference	64	3	fair	B
Little Cedar Creek	67f&i-37	67f&i	Reference	55	3	fair	B
Panther Creek	67h-8	67h	Impaired	53	3	fair	B
Dozier Creek	67g-19	67g	Impaired	49	3	fair	B
Trib to Little Armuchee Creek	67g-12	67g	Reference	48	3	fair	B
Polecat Creek	67g-6	67g	Impaired	48	3	fair	B
Sugar Creek	67g-1	67g	Impaired	40	3	fair	B
Dykes Creek	67f&i-27	67f&i	Reference	37	3	fair	B
Coke Oven Branch	67f&i-5	67f&i	Impaired	36	3	fair	B
Jones Branch	67f&i-33	67f&i	Impaired	36	3	fair	B
Town Branch	67f&i-11	67f&i	Impaired	31	4	poor	C
Noblet Creek	67g-7	67g	Impaired	31	4	poor	C
Black Branch	67f&i-1	67f&i	Impaired	26	4	poor	C
Trib to Tiger Creek	67g-2	67g	Ref/Removed	26	4	poor	C
Lick Creek	67g-9	67g	Impaired	21	4	poor	C
Alpine Creek	67f&i-20	67f&i	Impaired	19	5	very poor	C
Trib to Armuchee Creek	67g-15	67g	Reference	17	5	very poor	C

Figure 72. 67f&i – Southern Limestone/Dolomite Valleys & Low Rolling Hills and Southern Dissected Ridges & Knobs.

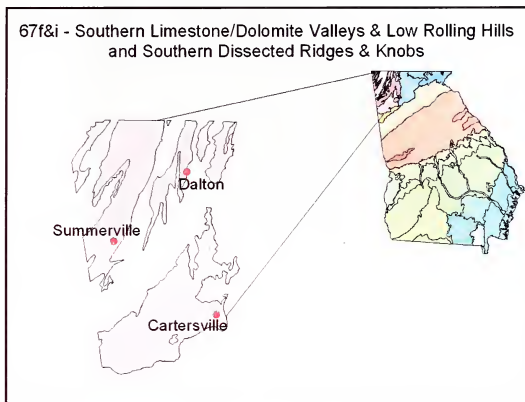


Figure 73. Typical Reference Stream – Subcoregion 67f&i.



Figure 74. Typical Impaired Stream – Subcoregion 67f&i.



Table 78. Index 67f&i.

Metric	Metric Category
EPT Taxa	Richness
Plecoptera Taxa	
% EPT	Composition
NCBI	Tolerance
Scraper Taxa	Functional Feeding Group
% Clinger	Habitat

Table 79. Descriptive Statistics for Reference Streams in Subcoregion 67f&i. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 5					Maximum
			5th	25th	50th	75th	95th	
EPT Taxa	1.0	6.0	7.0	11.0	14.0	15.0	16.6	17.0
Plecoptera Taxa	1.0	0.0	0.6	3.0	3.0	6.0	6.0	6.0
% EPT	1.0	17.9	18.8	22.5	34.2	42.5	48.5	50.0
NCBI	0.8	3.7	3.7	3.9	4.4	4.8	4.9	4.9
Scraper Taxa	0.8	5.0	5.0	5.0	6.0	7.0	7.0	7.0
% Clinger	1.0	26.7	27.8	32.1	36.3	45.0	55.7	58.3

Figure 75. Discriminating Index Characteristic between Reference and Impaired Streams for 67f&i.

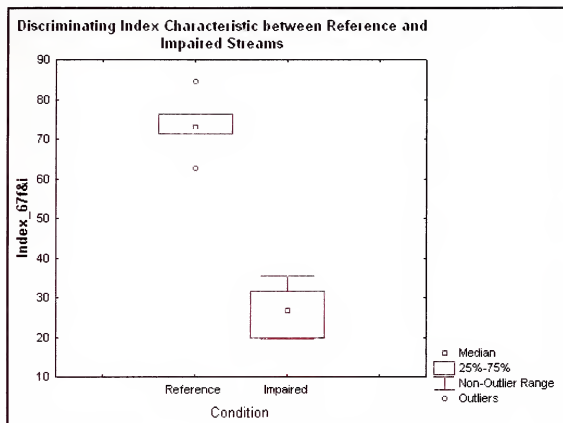


Table 80. Description of Numeric Ranking for Subcoregion 67f&i. n=all reference and impaired sites in Subcoregion 67f&i.

Index Score	Numeric Ranking	Percentile n = 10
81 and above	1	Above 95 th
74-80	2	Below 95 th , Above 75 th
28-73	3	Below 75 th , Above 25 th
21-27	4	Below 25 th , Above 5 th
20 and below	5	Below 5 th

Table 81. Stream Rating for Subcoregion 67f&i.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Cane Creek	67f&i-16	Reference	85	1	very good	A
Clarks Creek	67f&i-25	Reference	76	2	good	A
Little Cedar Creek	67f&i-37	Reference	73	3	fair	B
Armuchee Creek	67f&i-17	Reference	71	3	fair	B
Dykes Creek	67f&i-27	Reference	63	3	fair	B
Coke Oven Branch	67f&i-5	Impaired	35	3	fair	B
Town Branch	67f&i-11	Impaired	32	3	fair	B
Jones Branch	67f&i-33	Impaired	27	4	poor	C
Black Branch	67f&i-1	Impaired	20	5	very poor	C
Alpine Creek	67f&i-20	Impaired	19	5	very poor	C

Figure 76. 67g – Southern Shale Valleys.

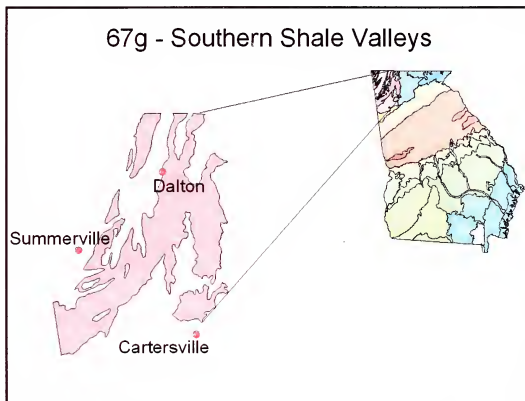


Figure 77. Typical Reference Stream – Subecoregion 67g.



Figure 78. Typical Impaired Stream – Subecoregion 67g.

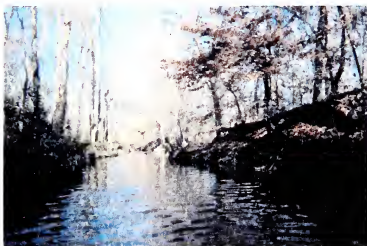


Table 82. Index 67g.

Metric	Metric Category
Plecoptera Taxa	Richness
% Hydropsychidae/Total Trichoptera	Composition
% Orthocladiinae/ Total Chironomidae	
Shredder Taxa	Functional Feeding Group
Collector Taxa	
Sprawler Taxa	Habitat

Table 83. Descriptive Statistics for Reference Streams in Subcoregion 67g.
 n = number of reference sites used. DE = discrimination efficiency between
 reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 4					Maximum
			5th	25th	50th	75th	95th	
Plecoptera Taxa	0.8	0.0	0.3	1.5	3.5	5.3	5.9	6.0
% Hydropsychidae/Total Trichoptera	0.8	0.0	0.0	0.0	13.9	29.2	32.5	33.3
% Orthocladiinae/ Total Chironomidae	1.0	27.5	28.5	32.3	48.1	67.2	79.1	82.1
Shredder Taxa	0.8	3.0	3.3	4.5	5.0	5.0	5.0	5.0
Collector Taxa	1.0	15.0	15.8	18.8	21.0	22.8	24.6	25.0
Sprawler Taxa	0.6	9.0	9.0	9.0	9.5	11.5	15.1	16.0

Figure 79. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 67g.

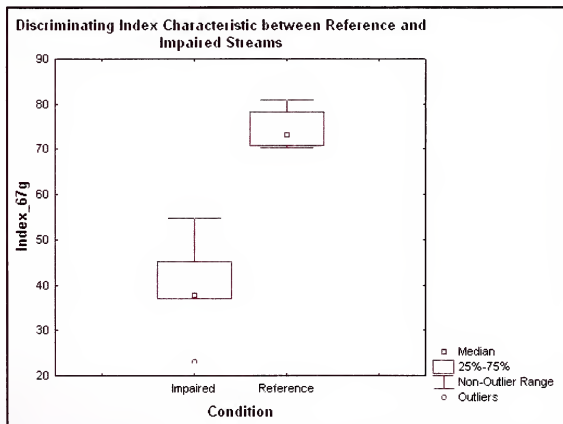


Table 84. Description of Numeric Ranking for Subcoregion 67g. n=all reference and impaired sites in Subcoregion 67g.

Index Score	Numeric Ranking	Percentile n = 10
78 and above	1	Above 95th
71-77	2	Below 95 th , Above 75th
38-70	3	Below 75 th , Above 25th
30-37	4	Below 25 th , Above 5th
29 and below	5	Below 5 th

Table 85. Stream Rating for Subcoregion 67g.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Moss Creek	67g-13	Reference	81	1	very good	A
Little Armuchee Creek	67g-11	Reference	76	2	good	A
Trib to Armuchee Creek	67g-15	Reference	71	2	good	A
Trib to Little Armuchee Creek	67g-12	Reference	70	3	fair	B
Noblet Creek	67g-7	Impaired	55	3	fair	B
Dozier Creek	67g-19	Impaired	45	3	fair	B
Lick Creek	67g-9	Impaired	38	3	fair	B
Polecat Creek	67g-6	Impaired	37	4	poor	C
Trib to Tiger Creek	67g-2	Ref/Removed	36	4	poor	C
Sugar Creek	67g-1	Impaired	23	5	very poor	C

Figure 80. 67h-Southern Sandstone Ridges.

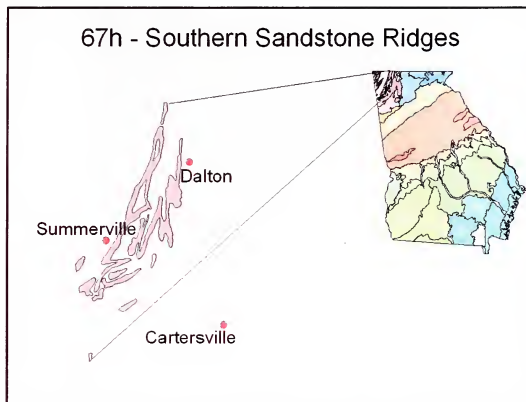


Figure 81. Typical Reference Stream – Subcoregion 67h.



Figure 82. Typical Impaired Stream – Subcoregion 67h.



Table 86. Index 67h.

Metric	Metric Category
Plecoptera Taxa	Richness
% Gastropoda	Composition
% Tolerant Individuals	Tolerance
HBI	
Scraper Taxa	Functional Feeding Group
Swimmer Taxa	Habitat

Table 87. Descriptive Statistics for Reference Streams in Subcoregion 67h. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 4					Maximum
			5th	25th	50th	75th	95th	
Plecoptera Taxa	0.5	3.0	3.0	3.0	3.5	5.0	7.4	8.0
% Gastropoda	1.0	21.0	21.5	23.4	25.6	28.9	33.3	34.4
% Tolerant Individuals	1.0	3.4	4.0	6.2	7.4	8.2	9.0	9.3
HBI	1.0	3.0	3.0	3.2	3.3	3.5	3.7	3.8
Scraper Taxa	1.0	6.0	6.2	6.8	7.0	8.3	11.3	12.0
Swimmer Taxa	1.0	0.0	0.3	1.5	2.0	2.0	2.0	2.0

Figure 83. Discriminating Index Characteristic between Reference and Impaired Streams for 67h.

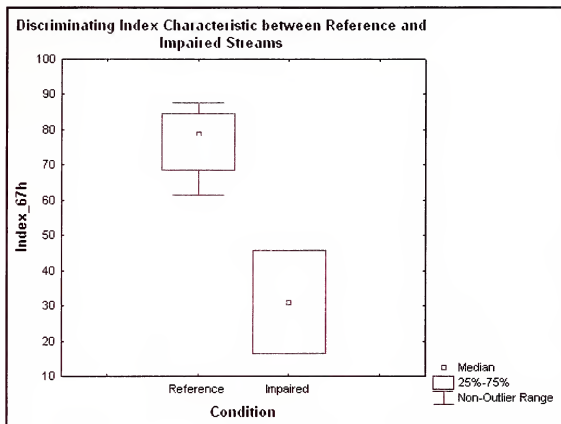


Table 88. Description of Numeric Ranking for Subcoregion 67h. n=all reference and impaired sites in subcoregion 67h.

Index Score	Numeric Ranking	Percentile n = 6
86 and above	1	Above 95th
80-85	2	Below 95 th , Above 75th
51-79	3	Below 75 th , Above 25th
25-50	4	Below 25 th , Above 5th
24 and below	5	Below 5 th

Table 89. Stream Rating for Subcoregion 67g.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Ranking
East Chicamagua Creek	67h-2	Reference	81	1	very good	A
Swamp Creek	67h-3	Reference	76	2	good	A
Snake Creek	67h-4	Reference	61	3	fair	B
Kings Creek	67h-9	Reference	88	3	fair	B
Trib to Ruff Creek	67h-5	Impaired	46	4	poor	C
Panther Creek	67h-8	Impaired	17	5	very poor	C

Figure 84. 68 – Southwestern Appalachians.

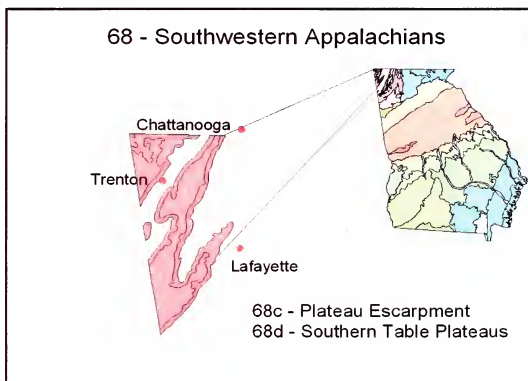


Figure 85. Typical Reference Stream – Subecoregion 68c&d.



Figure 86. Typical Impaired Stream – Subecoregion 68c&d.



Table 90. Index 68c&d.

Metric	Metric Category
Plecoptera Taxa	Richness
% Hydropsychidae/Total Trichoptera	Composition
% Tanypodinae/Total Chironomidae	
NCBI	Tolerance
Scraper Taxa	Functional Feeding Group
% Clinger	Habitat

Table 91. Descriptive Statistics for Reference Streams in Subcoregion 68c&d. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 4					Maximum
			5th	25th	50th	75th	95th	
Plecoptera Taxa	0.8	3.0	3.2	3.8	4.0	4.0	4.0	4.0
% Hydropsychidae/Total Trichoptera	0.6	0.0	0.0	0.0	2.1	6.1	10.6	11.8
% Tanypodinae/Total Chironomidae	0.8	0.6	1.4	4.5	9.9	14.3	15.2	15.4
NCBI	1.0	2.9	3.1	3.8	4.3	4.8	5.7	5.9
Scraper Taxa	0.8	1.0	1.5	3.3	4.5	5.5	6.7	7.0
% Clinger	0.6	0.8	5.6	24.9	34.5	36.0	36.1	36.1

Figure 87. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 68c&d.

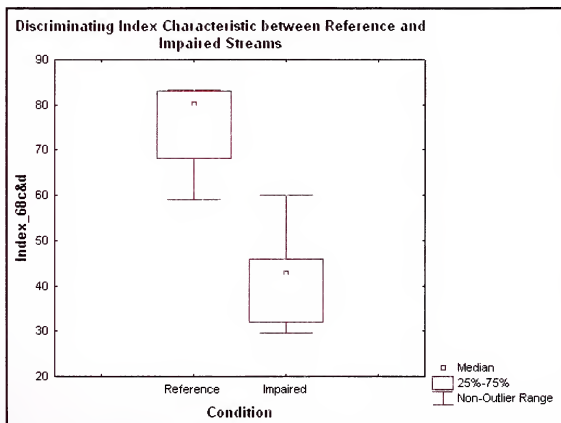


Table 92. Description of Numeric Ranking for Subcoregion 68c&d. n=all reference and impaired sites in Subcoregion 68c&d.

Index Score	Numeric Ranking	Percentile n = 9
83 and above	1	Above 95 th
77-82	2	Below 95 th , Above 75 th
43-76	3	Below 75 th , Above 25 th
31-42	4	Below 25 th , Above 5 th
30 and below	5	Below 5 th

Table 93. Stream Rating for Subcoregion 68c&d.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Ranking
Daniels Creek	68c&d-6	Reference	83	1	very good	A
Bear Creek	68c&d-5	Reference	83	1	very good	A
Rock Creek	68c&d-4	Reference	77	2	good	A
Trib to Middle Fork Little River	68c&d-8	Impaired	60	3	fair	B
Allen Creek	68c&d-9	Reference	59	3	fair	B
Running Water Creek	68c&d-1	Impaired	46	3	fair	B
West Fork Little River	68c&d-7	Impaired	43	3	fair	B
Higdon Creek	68c&d-3	Impaired	32	4	poor	C
East Fork Little River	68c&d-10	Impaired	30	5	very poor	C

Figure 88. Ecoregion 75 – Southern Coastal Plain.

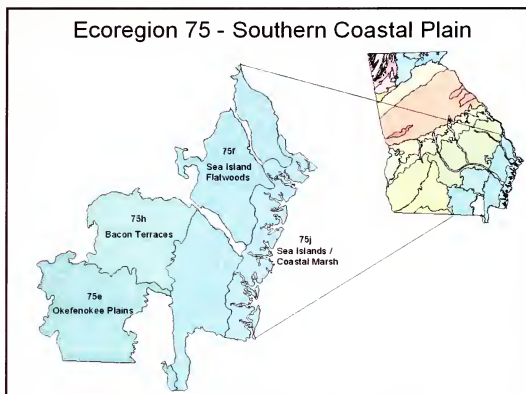


Table 94. Index 75.

Metric	Metric Category
% Non-Insect	Composition
% Oligochaeta	
% Odonata	
% Tanypodinae/Total Chironomidae	
Tolerant Taxa	Tolerance
% Tolerant Individuals	

Table 95. Descriptive Statistics for Reference Streams in Ecoregion 75. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 24					Maximum
			5th	25th	50th	75th	95th	
% Non-Insect	0.6	0.5	1.7	6.2	16.7	31.9	89.3	92.4
% Oligochaeta	0.7	0.0	0.0	0.7	1.0	3.9	6.5	8.1
% Odonata	0.5	0.0	0.0	0.0	0.0	0.5	3.3	9.2
% Tanypodinae/Total Chironomidae	0.5	0.0	0.0	0.0	0.2	1.8	16.3	34.4
Tolerant Taxa	0.6	0.0	1.0	2.8	6.0	8.0	19.9	21.0
% Tolerant Individuals	0.5	0.0	1.0	11.7	29.8	53.8	68.8	93.3

Figure 89. Discriminating Index Characteristic between Reference and Impaired Streams for Ecoregion 75.

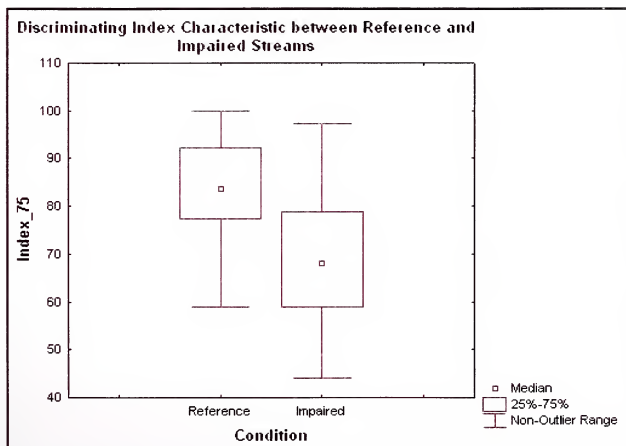


Table 96. Description of Numeric Ranking for Ecoregion 75. n=all reference and impaired sites in Ecoregion 75.

Index Score	Numeric Ranking	Percentile n = 60
94 and above	1	Above 95 th
84-93	2	Below 95 th , Above 75 th
65-83	3	Below 75 th , Above 25 th
50-64	4	Below 25 th , Above 5 th
49 and below	5	Below 5 th

Table 97. Stream Rating for Ecoregion 75.

Stream	StationID	Subcoregion	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Atwood Creek	75j-16	75j	Reference	100	1	very good	A
Trib to South Newport River	75j-10	75j	Reference	98	1	very good	A
Trib to Black Island Creek	75j-13	75j	Impaired	97	1	very good	A
Trib to Hurricane Creek	75h-35	75h	Reference	94	1	very good	A
Little Creek	75f-91	75f	Reference	94	1	very good	A
Trib Hudson Creek	75f-15	75f	Reference	92	2	good	A
Suwannee Creek	75e-23	75e	Reference	92	2	good	A
Dry Creek	75h-45	75h	Reference	92	2	good	A
Big Branch	75e-69	75e	Reference	91	2	good	A
Keene Bay Branch	75h-10	75h	Reference	91	2	good	A
Black Creek	75f-28	75f	Impaired	87	2	good	A
Trib to Little Ogeechee River	75j-2	75j	Impaired	87	2	good	A
Trib to Alapaha River	75e-78	75e	Reference	87	2	good	A
Trib to Little Satilla River	75j-26	75j	Reference	86	2	good	A
Trib to Brickhill	75j-37	75j	Reference	85	2	good	A
Airport Creek	75j-21	75j	Impaired	84	2	good	A
Yellow Bluff Creek	75j-24	75j	Impaired	84	2	good	A
Trib to Wilmington River	75j-4	75j	Impaired	83	3	fair	B
Cathard Creek	75f-95	75f	Reference	82	3	fair	B
Trib to White Oak Creek	75j-25	75j	Reference	82	3	fair	B
Trib Jones Creek	75j-5	75j	Reference	81	3	fair	B
White Branch	75j-41	75j	Reference	81	3	fair	B
Hatcher's Branch	75f-132	75f	Impaired	81	3	fair	B
Trib to Little Waverly Creek	75f-124	75f	Reference	80	3	fair	B
Bull Creek	75f-48	75f	Impaired	80	3	fair	B
Fullwood Creek	75e-20	75e	Impaired	79	3	fair	B

Table 97. Stream Rating for Ecoregion 75 (cont.).

Todd Creek	75j-31	75j	Reference	79	3	fair	B
Reynolds Creek	75f-127	75f	Impaired	78	3	fair	B
Ray Branch	75e-59	75e	Reference	76	3	fair	B
Clay Branch	75f-137	75f	Impaired	73	3	fair	B
Trib to Taylor Creek	75f-70	75f	Impaired	72	3	fair	B
Waverly Creek	75f-126	75f	Reference	71	3	fair	B
Raccoon Branch	75f-61	75f	Reference	70	3	fair	B
Reedy Creek	75e-54	75e	Impaired	70	3	fair	B
Cat Creek	75h-47	75h	Impaired	70	3	fair	B
Springfield Canal	75f-44	75f	Impaired	70	3	fair	B
Law Creek	75j-23	75j	Impaired	68	3	fair	B
Ashley Creek	75f-15	75f	Impaired	68	3	fair	B
Meetinghouse Branch	75e-60	75e	Reference	68	3	fair	B
Trib to Satilla River	75h-69	75h	Impaired	68	3	fair	B
Trib to Alapaha River	75e-3	75e	Impaired	66	3	fair	B
Burket Stream	75h-1	75h	Impaired	65	3	fair	B
Trib to Radcliffe Creek	75j-29	75j	Ref/Removed	65	3	fair	B
Pudding Creek	75e-2	75e	Impaired	65	3	fair	B
Trib to Alapaha	75h-60	75h	Reference	64	4	poor	C
Pond Fork	75h-70	75h	Impaired	64	4	poor	C
Trib to Black Island Creek	75j-12	75j	Impaired	64	4	poor	C
Trib to Sapelo River	75j-11	75j	Impaired	62	4	poor	C
Trib to Hoover Creek	75j-3	75j	Impaired	61	4	poor	C
Swain Creek	75e-36	75e	Impaired	59	4	poor	C
Otter Creek	75h-66	75h	Reference	59	4	poor	C
Pearson Creek	75e-8	75e	Impaired	59	4	poor	C
Newport River	75f-77	75f	Impaired	57	4	poor	C
Otter Creek	75e-61	75e	Impaired	56	4	poor	C
Briar Creek	75h-41	75h	Impaired	55	4	poor	C
Trib to Hoover Creek	75j-3-1	75j	Impaired	50	4	poor	C

Table 97. Stream Rating for Ecoregion 75 (cont.).

Moore Branch	75e-46	75e	Impaired	49	5	very poor	C
Mill Creek	75h-72	75h	Impaired	48	5	very poor	C
Canoochee Creek	75f-50	75f	Impaired	47	5	very poor	C
Haney's Creek	75f-45	75f	Impaired	44	5	very poor	C

Figure 90. 75e – Okefenokee Plains.

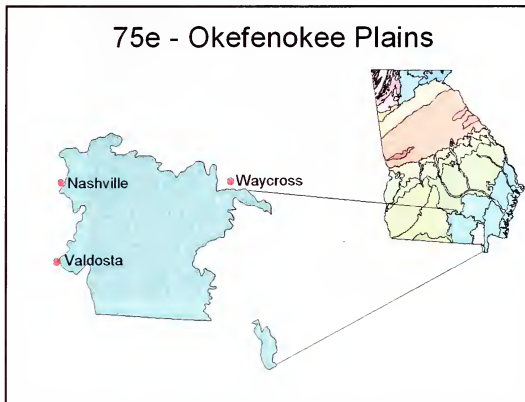


Figure 91. Typical Reference Stream – Subcoregion 75e.



Figure 92. Typical Impaired Stream – Subcoregion 75e.



Table 98. Index 75e.

Metric	Metric Category
% Non-Insect	Composition
% Oligochaeta	
% Isopoda	
% Odonata	
% Tolerant Individuals	Tolerance
% Filterer	Functional Feeding Group

Table 99. Descriptive Statistics for Reference Streams in Subcoregion 75e. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 5					Maximum
			5th	25th	50th	75th	95th	
% Non-Insect	0.9	6.1	6.6	8.9	13.9	15.4	17.4	17.9
% Oligochaeta	0.9	0.0	0.1	0.4	0.8	0.9	1.0	1.0
% Isopoda	0.6	4.4	4.9	6.8	8.7	12.1	14.4	15.0
% Odonata	0.6	0.0	0.0	0.0	0.0	0.4	0.8	0.8
% Tolerant Individuals	0.6	12.0	19.3	28.9	56.7	60.7	79.4	81.8
% Filterer	0.6	0.0	0.1	0.6	0.8	1.0	13.7	16.9

Figure 93. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 75e.

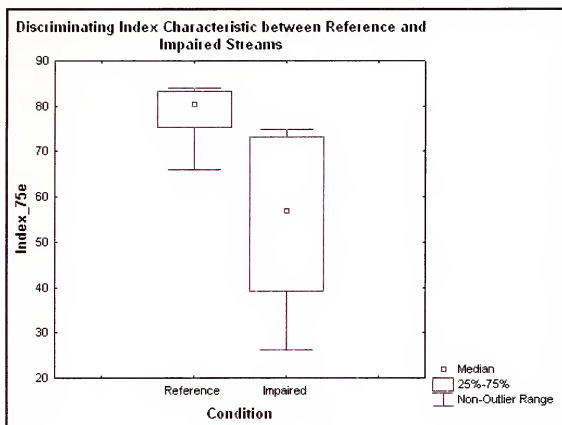


Table 100. Description of Numeric Ranking for Subcoregion 75e. n=all reference and impaired sites in Subcoregion 75e.

Index Score	Numeric Ranking	Percentile n = 13
84 and above	1	Above 95 th
75-83	2	Below 95 th , Above 75 th
53-74	3	Below 75 th , Above 25 th
31-52	4	Below 25 th , Above 5 th
30 and below	5	Below 5 th

Table 101. Stream Rating for Subcoregion 75e.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Ray Branch	75e-59	Reference	84	1	very good	A
Suwannoochee Creek	75e-23	Reference	83	2	good	A
Big Branch	75e-69	Reference	80	2	good	A
Trib to Alapaha River	75e-78	Reference	75	2	good	A
Pudding Creek	75e-2	Impaired	75	2	good	A
Reedy Creek	75e-54	Impaired	73	3	fair	B
Fullwood Creek	75e-20	Impaired	73	3	fair	B
Meetinghouse Branch	75e-60	Reference	66	3	fair	B
Trib to Alapaha River	75e-3	Impaired	62	3	fair	B
Otter Creek	75e-61	Impaired	52	4	poor	C
Moore Branch	75e-46	Impaired	45	4	poor	C
Swain Creek	75e-36	Impaired	34	4	poor	C
Pearson Creek	75e-8	Impaired	26	5	very poor	C

Figure 94. 75f – Sea Island Flatwoods.

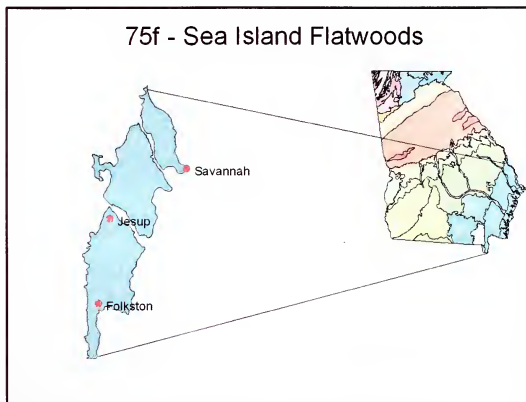


Figure 95. Typical Reference Stream – Subcoregion 75f.



Figure 96. Typical Impaired Stream – Subcoregion 75f.



Table 102. Index 75f.

Metric	Metric Category
% Oligochaeta	Composition
% Tanypodinae/Total Chironomidae	
Tolerant Taxa	Tolerance
% Filterer	Functional Feeding Group

Table 103. Descriptive Statistics for Reference Streams in Subcoregion 75f.
 n = number of reference sites used. DE = discrimination efficiency between
 reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 4					Maximum
			5th	25th	50th	75th	95th	
% Oligochaeta	0.7	0.0	0.0	0.0	1.9	4.8	7.4	8.1
% Tanypodinae/Total Chironomidae	0.8	0.0	0.0	0.0	0.0	0.1	0.4	0.5
Tolerant Taxa	0.8	4.0	4.2	4.8	6.5	8.5	9.7	10.0
% Filterer	0.7	0.0	0.0	0.0	0.2	0.6	0.9	0.9

Figure 97. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 75f.

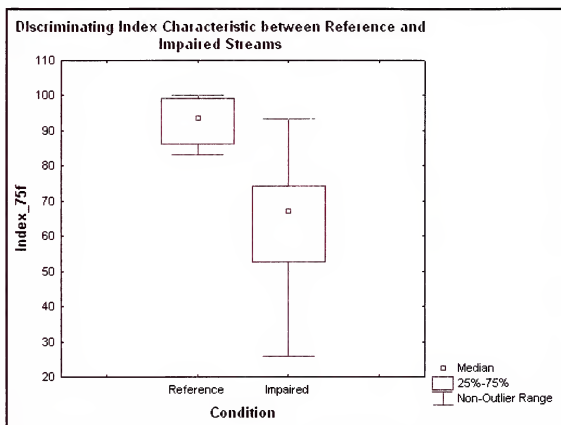


Table 104. Description of Numeric Ranking for Subcoregion 75f. n=all reference and impaired sites in Subcoregion 75f.

Index Score	Numeric Ranking	Percentile n = 15
98 and above	1	Above 95 th
86-97	2	Below 95 th , Above 75 th
60-85	3	Below 75 th , Above 25 th
41-59	4	Below 25 th , Above 5 th
40 and below	5	Below 5 th

Table 105. Stream Rating for Subcoregion 75f.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Raccoon Branch	75f-61	Reference	100	1	very good	A
Little Creek	75f-91	Reference	98	1	very good	A
Black Creek	75f-28	Impaired	93	2	good	A
Cathead Creek	75f-95	Reference	89	2	good	A
Waverly Creek	75f-126	Reference	83	3	fair	B
Springfield Canal	75f-44	Impaired	79	3	fair	B
Bull Creek	75f-48	Impaired	74	3	fair	B
Trib to Taylor Creek	75f-70	Impaired	74	3	fair	B
Clay Branch	75f-137	Impaired	69	3	fair	B
Hatcher's Branch	75f-132	Impaired	67	3	fair	B
Ashley Creek	75f-15	Impaired	65	3	fair	B
Newport River	75f-77	Impaired	55	4	poor	C
Reynolds Creek	75f-127	Impaired	53	4	poor	C
Canoochee Creek	75f-50	Impaired	47	4	poor	C
Haney's Creek	75f-45	Impaired	26	5	very poor	C

Figure 98. 75h – Bacon Terraces.

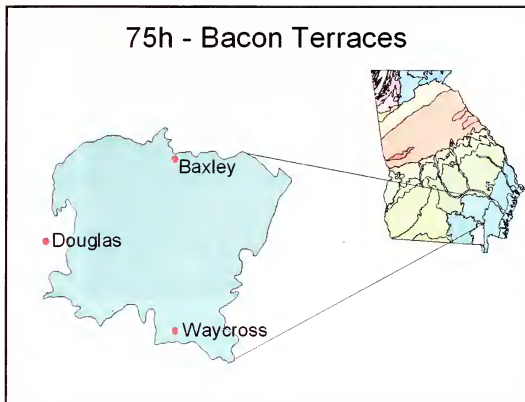


Figure 99. Typical Reference Stream – Subcoregion 75h.



Figure 100. Typical Impaired Stream – Subcoregion 75h.



Table 106. Index 75h.

Metric	Metric Category
% Oligochaeta	Composition
% Tolerant Individuals	Tolerance
HBI	
% Shredder	Functional Feeding Group
Collector Taxa	
% Filterer	

Table 107. Descriptive Statistics for Reference Streams in Subcoregion 75h. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 5					Maximum
			5th	25th	50th	75th	95th	
% Oligochaeta	0.8	0.0	0.2	0.8	1.3	4.1	4.2	4.2
% Tolerant Individuals	0.8	8.9	10.4	16.3	37.2	41.3	52.3	55.0
HBI	0.5	5.2	5.3	5.4	6.6	7.0	7.1	7.1
% Shredder	0.8	0.0	0.2	1.0	1.3	2.3	5.8	6.7
Collector Taxa	0.5	7.0	7.2	8.0	11.0	15.0	15.8	16.0
% Filterer	0.5	0.0	0.0	0.0	2.5	9.6	20.9	23.7

Figure 101. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 75h.

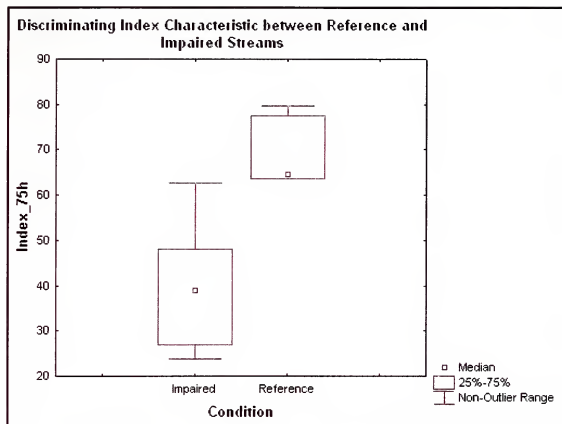


Table 108. Description of Numeric Ranking for Subcoregion 75h. n=all reference and impaired sites in Subcoregion 75h.

Index Score	Numeric Ranking	Percentile n = 11
77 and above	1	Above 95 th
65-76	2	Below 95 th , Above 75 th
39-64	3	Below 75 th , Above 25 th
25-38	4	Below 25 th , Above 5 th
24 and below	5	Below 5 th

Table 109. Stream Rating for Subcoregion 75h.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Otter Creek	75h-66	Reference	80	1	very good	A
Keene Bay Branch	75h-10	Reference	77	1	very good	A
Dry Creek	75h-45	Reference	65	2	good	A
Trib to Alapaha	75h-60	Reference	64	3	fair	B
Trib to Hurricane Creek	75h-35	Reference	64	3	fair	B
Pond Fork	75h-70	Impaired	63	3	fair	B
Burket Stream	75h-1	Impaired	48	3	fair	B
Cat Creek	75h-47	Impaired	44	3	fair	B
Briar Creek	75h-41	Impaired	34	4	poor	C
Trib to Satilla River	75h-69	Impaired	27	4	poor	C
Mill Creek	75h-72	Impaired	24	5	very poor	C

Figure 102. 75j-Sea Islands/Coastal Marsh.

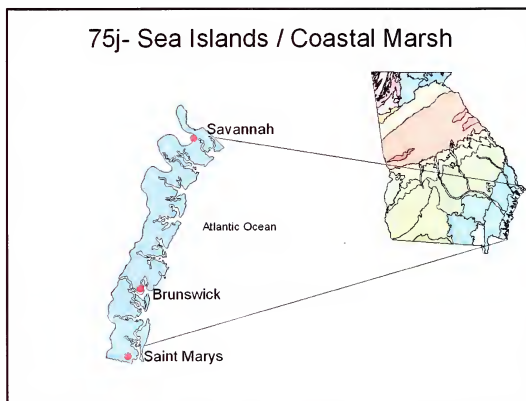


Figure 103. Typical Reference Stream – Subcoregion 75j.



Figure 104. Typical Impaired Stream – Subcoregion 75j.



Table 110. Index 75j.

Metric	Metric Category
% Non-Insect	Composition
% Oligochaeta	
% Tolerant Individuals	Tolerance
Shredder Taxa	Functional Feeding Group

Table 111. Descriptive Statistics for Reference Streams in Subcoregion 75j.
 n = number of reference sites used. DE = discrimination efficiency between
 reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 10					Maximum
			5th	25th	50th	75th	95th	
% Non-Insect	0.6	1.8	1.9	14.3	29.1	42.3	84.4	92.4
% Oligochaeta	0.5	0.0	0.4	1.0	1.9	3.9	6.3	6.7
% Tolerant Individuals	0.6	0.0	0.4	3.2	19.0	46.4	62.2	25.9
Shredder Taxa	0.5	0.0	0.0	1.0	1.0	1.8	2.0	2.0

Figure 105. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 75j.

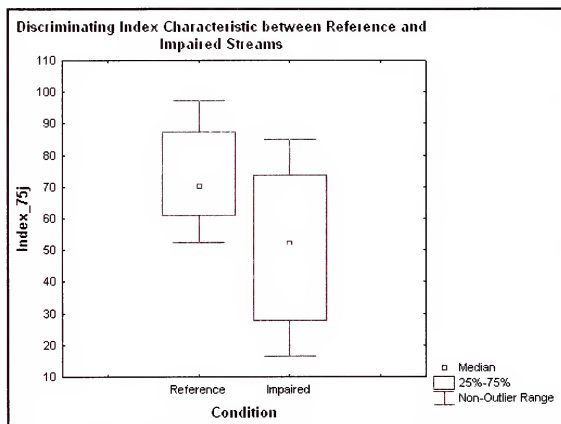


Table 112. Description of Numeric Ranking for Subcoregion 75j. n=all reference and impaired sites in Subcoregion 75j.

Index Score	Numeric Ranking	Percentile n = 21
92 and above	1	Above 95 th
77-91	2	Below 95 th , Above 75 th
52-76	3	Below 75 th , Above 25 th
27-51	4	Below 25 th , Above 5 th
26 and below	5	Below 5 th

Table 113. Stream Rating for Subcoregion 75j.

Stream	StationID	Tidal Influenced	Condition	Index Score	Numeric Ranking	Narrative Description
Trib to South Newport River	75j-10	No	Reference	97	1	very good
Trib Hudson Creek	75j-15	No	Reference	91	2	good
Atwood Creek	75j-16	Yes	Reference	87	2	good
Trib to White Oak Creek	75j-25	No	Reference	77	2	good
Trib to Little Satilla River	75j-26	No	Reference	73	3	fair
Trib to Brickhill	75j-37	Yes	Reference	68	3	fair
Todd Creek	75j-31	Yes	Reference	65	3	fair
White Branch	75j-41	Yes	Reference	61	3	fair
Trib to Little Waverly Creek	75f-124	Yes	Reference	52	3	fair
Trib Jones Creek	75j-5	Yes	Reference	52	3	fair
Trib to Radcliffe Creek	75j-29	No	Ref/Removed	47	4	poor
Trib to Black Island Creek	75j-13	No	Impaired	85	2	good
Trib to Little Ogeechee River	75j-2	No	Impaired	80	2	good
Trib to Wilmington River	75j-4	No	Impaired	74	3	fair
Airport Creek	75j-21	Yes	Impaired	63	3	fair
Trib to Black Island Creek	75j-12	No	Impaired	53	3	fair
Yellow Bluff Creek	75j-24	Yes	Impaired	51	4	poor
Trib to Sapelo River	75j-11	No	Impaired	30	4	poor
Trib to Hoover Creek	75j-3	Yes	Impaired	28	4	poor
Law Creek	75j-23	Yes	Impaired	27	4	poor
Trib to Hoover Creek	75j-3-1	Yes	Impaired	16	5	very poor

Table 114. Index 75j Nontidal.

Metric	Metric Category
% Amphipoda	Composition
% Oligochaeta	
% Tanypodinae/Total Chironomidae	
% HBI	Tolerance
% Shredder	Functional Feeding Group

Table 115. Descriptive Statistics for Reference Streams in Subcoregion 75j Nontidal. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 4					Maximum
			5th	25th	50th	75th	95th	
% Amphipoda	0.8	0.4	1.1	3.8	11.0	20.4	28.4	30.4
% Oligochaeta	0.8	0.8	0.9	0.9	1.3	2.7	5.2	5.8
% Tanypodinae/Total Chironomidae	1.0	0.6	0.6	0.7	1.0	1.4	1.6	1.6
% HBI	0.8	6.9	7.0	7.2	7.3	7.4	7.6	7.6
% Shredder	0.6	1.0	1.0	1.2	1.3	2.0	3.7	4.2

Figure 106. Discriminating Index Characteristic between Reference and Impaired Streams for Subcoregion 75j Nontidal.

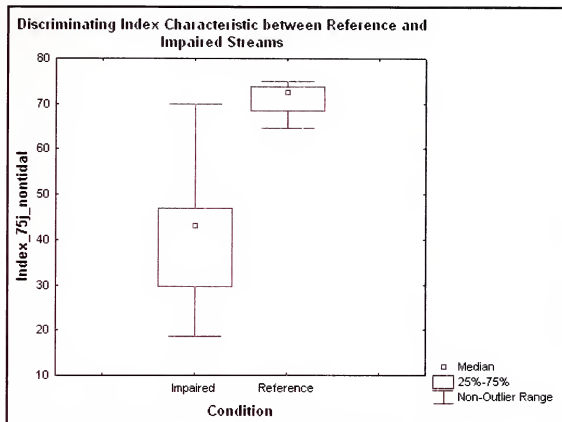


Table 116. Description of Numeric Ranking for Subcoregion 75j Nontidal. n=all reference and impaired sites in subcoregion 75j nontidal.

Index Score	Numeric Ranking	Percentile n = 10
74 and above	1	Above 95 th
72-73	2	Below 95 th , Above 75 th
44-71	3	Below 75 th , Above 25 th
24-43	4	Below 25 th , Above 5 th
23 and below	5	Below 5 th

Table 117. Stream Rating for Subcoregion 75j Nontidal.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Trib to White Oak Creek	75j-25	Reference	75	1	very good	A
Trib Hudson Creek	75j-15	Reference	73	2	good	A
Trib to Little Satilla River	75j-26	Reference	72	2	good	A
Trib to Black Island Creek	75j-13	Impaired	70	3	fair	B
Trib to South Newport River	75j-10	Reference	65	3	fair	B
Trib to Radcliffe Creek	75j-29	ref/removed	56	3	fair	B
Trib to Black Island Creek	75j-12	Impaired	47	3	fair	B
Trib to Little Ogeechee River	75j-2	Impaired	43	4	poor	C
Trib to Sapelo River	75j-11	Impaired	30	4	poor	C
Trib to Wilmington River	75j-4	Impaired	19	5	very poor	C

Table 118. Index 75j Tidal.

Metric	Metric Category
Simpson's D	Richness
% Non-Insect	Composition
% Tolerant Individuals	Tolerance
% Shredder	Functional Feeding Group
% Predator	

Table 119. Descriptive Statistics for Reference Streams in Subcoregion 75j Tidal. n = number of reference sites used. DE = discrimination efficiency between reference and impaired conditions.

Metrics	DE	Minimum	Percentile n = 6					Maximum
			5th	25th	50th	75th	95th	
Simpson's D	0.6	0.1	0.1	0.2	0.2	0.4	0.8	0.9
% Non-Insect	0.8	1.8	1.9	7.4	27.2	63.7	88.0	92.4
% Tolerant Individuals	0.6	0.9	3.0	9.6	30.1	52.3	65.4	69.5
% Shredder	0.8	0.0	0.0	0.8	3.5	7.3	12.9	14.4
% Predator	0.6	0.0	0.0	0.2	1.1	1.4	5.5	6.8

Figure 107. Discriminating Index Characteristic between Reference and Impaired Stream for Subcoregion 75j Tidal.

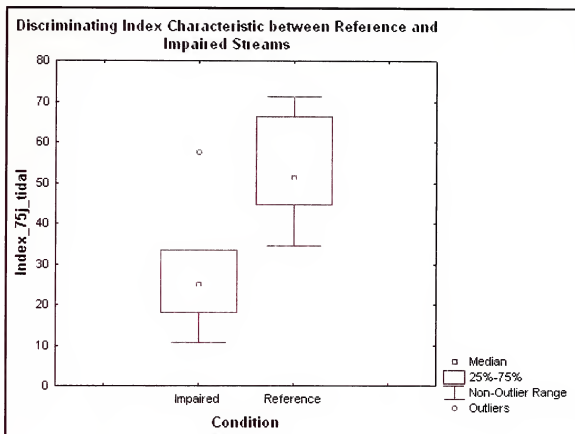


Table 120. Description of Numeric Ranking for Subcoregion 75j Tidal. n=all reference and impaired sites in Subcoregion 75j Tidal.

Index Score	Numeric Ranking	Percentile n = 11
68 and above	1	Above 95 th
57-67	2	Below 95 th , Above 75 th
29-56	3	Below 75 th , Above 25 th
14-28	4	Below 25 th , Above 5 th
13 and below	5	Below 5 th

Table 121. Stream Rating for Subcoregion 75j Tidal.

Stream	StationID	Condition	Index Score	Numeric Ranking	Narrative Description	Stream Rating
Trib to Brickhill	75j-37	Reference	71	1	very good	A
Todd Creek	75j-31	Reference	64	2	good	A
Airport Creek	75j-21	Impaired	58	2	good	A
Trib to Little Waverly Creek	75f-124	Reference	57	2	good	A
Trib Jones Creek	75j-5	Reference	45	3	fair	B
Atwood Creek	75j-16	Reference	45	3	fair	B
White Branch	75j-41	Reference	34	3	fair	B
Yellow Bluff Creek	75j-24	Impaired	33	3	fair	B
Law Creek	75j-23	Impaired	25	4	poor	C
Trib to Hoover Creek	75j-3-1	Impaired	18	4	poor	C
Trib to Hoover Creek	75j-3	Impaired	11	5	very poor	C

Table 122. Correlations between Index Scores and Percent Land Use: Ecoregion Level.

Ecoregion	Land Use		
	% Natural	% Urban	% Total Agriculture
45	0.47	-0.63	-0.02
65	0.49	-0.07	-0.50
66	0.23	0.05	-0.60
67	0.51	-0.42	-0.37
68	0.10	0.39	-0.31
75	0.40	-0.18	-0.35

Table 123. Correlations between Index Scores and Percent Land Use: Subcoregion Level.

Subcoregion	Land Use		
	% Natural	% Urban	% Total Agriculture
45a	0.74	-0.88	0.39
45b	0.79	-0.73	0.13
45c	0.53	-0.14	-0.51
45d	-0.17	-0.64	-0.49
45h	0.68	-0.18	-0.63
65c	0.65	-0.46	-0.29
65d	0.77	-0.63	-0.26
65g	0.73	-0.16	-0.69
65h	0.61	0.28	-0.81
65k	0.75	-0.18	-0.70
65l	0.44	0.05	-0.47
65o	-0.20	0.35	0.44
66d	0.00	-0.79	-0.47
66g	0.91	0.25	-0.78
66j	-0.27	-0.23	-0.50
67f&i	0.83	-0.64	-0.52
67g	0.52	-0.32	-0.23
67h	0.48	0.97	0.94
75e	0.53	-0.07	-0.53
75f	0.70	-0.58	-0.15
75h	0.28	-0.53	-0.19
75j	0.33	-0.29	0.02
75j nontidal	0.46	-0.45	-0.09
75j tidal	0.80	-0.75	-0.13

Discussion

The Multimetric Rating System can be used to guide non-point source regulations for Georgia's streams. Using the macroinvertebrate community as a biomonitor, the Multimetric Rating System uses fundamental characteristics of the stream community to determine the overall health or condition of that community. By using macroinvertebrate assemblages as a reference for stream condition, the Multimetric Rating System can be used to describe the condition for the entire stream community and therefore determine overall stream condition or health.

The multimetric method is a valid assessor of biological systems because of its ability to describe interactions among several levels of the lotic community, to discriminate between natural and impaired conditions, and to detect a range of stream conditions (Barbour *et al.* 1995). The Multimetric Rating System determines levels of impairment within the subcoregion or ecoregion level relative to the least impaired condition in the same region. By developing indices based on multiple metric data, the Multimetric Rating System can be used as a tool for making sound water management decisions.

The Multimetric Rating System describes each stream's condition within a subcoregion or ecoregion as compared to the reference stream condition; the more a stream varies from the reference condition the more impaired the stream. Streams classified as impaired were selected based on a gradient of impaired conditions. Several reference streams were sampled in each subcoregion to

provide an average reference condition. Using “least impaired streams” as a reference condition, each stream received a rating at the ecoregion and subecoregion level.

When developing the Multimetric Rating System, it was determined that each stream would be described according to the macroinvertebrate data and not to the stream’s original classification. As a result, all streams were rated independent of their reference or impaired classification. For instance, an impaired stream may rate as a “B” or “good” stream, and vice versa, a reference stream may rate as a “C” or “poor/very poor” stream.

In this study, 1994 land use data were used to originally classify streams as reference or impaired. In the field, streams classified as reference were assessed for their current and most accurate observational condition. Because of the time delay between the land use data collection and the collection of data for this project, sometimes present conditions did not always correspond with the 1994 land use data. Candidate reference streams were automatically excluded if they were channelized, exhibited a limited or nonexistent natural stream buffer, and/or if the stream bed was not in a natural condition (e.g. filled with silt). Streams were also excluded, if the water quality did not meet reference criteria (see Gore *et al.* 2004). For example, one stream was excluded as a candidate reference stream for an extremely high phosphorus value. On the other hand, streams originally classified as impaired on a few occasions appeared to be in a reference condition status, by best professional judgment of the field collection

teams. However, in each case, the final stream assessment was based on macroinvertebrate data, as well as observational data.

Once stream indices were developed, several trends were observed. Within each ecoregion, the discrimination efficiencies (DE) for each individual subecoregion tended to be much higher than the ecoregion level DE. Smaller ecoregions containing fewer subecoregions were found to have higher DE than ecoregions containing geographically widespread subecoregions. This reveals that subecoregion level indices more easily discriminate between reference and impaired conditions than ecoregion level indices. As a result, it was found that multimetrics indices are most effective when used to describe stream condition on a more localized scale such as the subecoregion level.

When streams within a subecoregion vary widely, it can be shown that streams should be grouped into statistically similar categories. The Southern Coastal Plain Ecoregion (75) is one example. The Southern Coastal Plain Ecoregion (75) is located along the Georgia coast. In this area, many streams are tidally-influenced resulting in different chemical, physical, and biological characteristics than streams without tidal effects. In the Sea Islands/Coastal Marsh Subecoregion (75j), approximately half of the streams sampled were tidally influenced. When the Sea Islands/Coastal Marsh Subecoregion (75j) index was developed, the discrimination efficiency was approximately 50 percent. Tidal streams and non-tidal stream were grouped to determine if separate indices would better describe the subecoregion. One index included tidal streams from

Sea Islands/Coastal Marsh Subecoregion (75j) and one tidal stream from Sea Island Flatwoods Subecoregion (75f). In the non-tidal index, all streams were non-tidal streams from Sea Islands/Coastal March Subecoregion (75j). It was found that both indices had higher discrimination efficiencies than the original combined index. It can be concluded, in some cases, that streams in subecoregions require further classification in order to describe the lotic ecosystems with a higher level of precision.

At the ecoregion level, discrimination efficiencies ranged from 67-100 percent with an average of 81 percent. When the number of subecoregions increased in an ecoregion, the discrimination efficiency decreased. Ecoregions with more subecoregions have more variability and, as a result, indices become less accurate when discriminating between reference and impaired conditions. Subecoregion level indices had discrimination efficiencies that were on average 10 percent higher than ecoregion level indices. This result suggests that subecoregion-level-indices should be used for water management purposes.

When indices were developed, metrics were chosen primarily by discrimination efficiency and secondly by metric category. Metrics were selected so that each functional or organizational category would be represented in order to most accurately describe the benthic community as they exist. All indices at the ecoregion and subecoregion level included metrics from most metric categories except Southern Coastal Plain Ecoregion (75). Due to low discrimination efficiency, the Southern Coastal Plain Ecoregion index only had

metrics from composition and tolerance categories. In Southern Coastal Plain Ecoregion (75), subecoregion indices had metrics from composition, tolerance, and functional feeding group categories. The only exception was Sea Islands/Coastal Marsh Subecoregion (75j) tidal, which had one richness metric. In Southern Coastal Plain Ecoregion (75), stream conditions were found to be significantly different based on the overall ability of metric categories to discriminate between reference and impaired conditions.

All streams were selected based on GIS land use data and discrete screening filters and the resulting indices and rating system were developed to describe stream conditions (Gore *et al.* 2004). To determine if any relationships were present between each the index score and percent land use, the Pearson Product-Moment Correlation was used (MDEQ 2003). Index scores and percent-land-use did not strongly correlate at the subecoregion level and no significant correlations were found at the ecoregion level. Although the relationships may not have been significant, a trend was observed between index scores and the percent land use. Index scores were most often positively correlated with percent natural land use and negatively correlated with percent urban and total agriculture land use. As shown in Table 122, the index score has the ability to detect changes in land use and whether this change has a positive or negative effect on the natural condition within each ecoregion or subecoregion.

In this study, several problems have been noted in the process of collecting stream data. Although streams were sampled in all ecoregions of

Georgia except for the Okefenokee Swamp, the sample size for each ecoregion and subcoregion was limited. Most streams were only sampled once, so there are no time comparison data. Sampling took place during the winter macroinvertebrate season between September and February. Streams sampled early or late in the season may have a higher level of variation between sites than streams sampled within the same month (Merritt et al. 1996). Stream data in this study may not be comparable to samples taken during the summer months.

One major problem this study encountered was record low stream flows. Sampling took place between the years of 2000-2003. Georgia entered a drought in 1999 and that drought was not relieved until the Fall of 2002. As a result, data were collected, for the most part, during a drought. Some streams in Southeast Georgia were completely dry and were not sampled until the winter of 2003. The results of this study were influenced by the lack of precipitation during the sampling seasons, therefore the impact of drought conditions on the macroinvertebrate data is not known. Further research is required to determine the full impact of Georgia's drought on the results of this study.

Lastly, as with all scientific studies, researcher error may have affected the results of this study. At each level of data collection and analysis, researcher error was monitored through quality control and quality assurance, as noted in the Quality Assurance Project Plan (QAPP): Ecoregions Reference Site Project

for Wadeable Streams in Georgia (Columbus State University 2000, Ferring 2005).

The Multimetric Rating System (MRS) has many applications for water resource management. The MRS is simple to use, relatively inexpensive, and an extremely versatile water management tool. By grouping streams into three stream condition categories, the MRS is a simple method for determining biological and ecological conditions within a stream system, as well as, overall water quality. The MRS requires only limited technical knowledge, which allows ease of use for water managers.

As prescribed by Section 319 of the Clean Water Act, the Multimetric Rating System (MRS) may be used to classify wadeable streams in Georgia. By using the three MRS rating categories, streams may be grouped into three health conditions. The MRS may be used to prioritize the Department of Natural Resource's efforts to identify, maintain, and restore wadeable streams in Georgia.

The Multimetric Rating System (MRS) is a cost-effective water monitoring tool. Based on macroinvertebrate sampling data, sampling cost is relatively inexpensive using low-tech sampling methods (Williams 2004). The MRS is also economical because can be used repeatedly to access individual streams for a specific region where a reference index has been developed.

State programs and local municipalities may find the Multimetric Rating System (MRS) useful for determining how to distribute public funds. For

example, the MRS can identify streams which rate "C" (poor or very poor) for a specific ecoregion or subcoregion. With limited resources, water resource managers may decide to devote time and funds to monitoring and restoring streams that are in the most critical condition.

As mandated by the Environmental Protection Agency, each state is required to develop water quality standards. The Multimetric Rating System (MRS) can be used to determine water quality and develop water quality standards. Since the MRS is based on benthic macroinvertebrate data, this type of data can be used to characterize the stream condition, and therefore water quality present over a period of time. Using water quality measures for a range of stream conditions, water quality standards may be developed for a certain ecoregion or subcoregion. The MRS provides information specific to an ecoregion or subcoregion making water quality standards more accurate for a specific area.

The Multimetric Rating System (MRS) can be applied to geographic regions within the United States and throughout the world. By sampling the macroinvertebrate community and developing a multimetric index, the MRS can describe any stream community and its biological condition. Since the MRS is based on a multimetric system, this multifaceted approach will be able to accurately determine stream condition.

In conclusion, the Multimetric Rating System should be used as a tool for determining the overall condition of Georgia's streams. The Multimetric Rating

System is also applicable for determining stream conditions, water management decisions, and water quality criteria. Using the Multimetric Rating System, water quality standards would encompass the condition of the entire water community including the physical, chemical, and biological elements. Using Rapid Bioassessment Protocol, a proven EPA assessment method, the Multimetric Rating System for Streams in Georgia was developed as a management tool specifically for Georgia's streams. The Multimetric Rating System, a standard method for determining stream condition, may be adapted to apply to areas across the United States and throughout the world.

References

- Barbour, M. T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water: Washington, D.C.
- Barbour, M. T. 1997. The Re-invention of Biological Assessment in the U. S. Human and Ecological Risk Assessment 3: 933-940.
- Barbour, M. T., J. B. Stribling, and J. R. Karr. 1995. Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Ed. Davis, W. S. and T. P. Simon. Lewis Publishers: New York. 415. (63-77).
- Berry, J. F. and M. S. Dennison. 2000. The Environmental Law and Compliance Handbook. McGraw-Hill: New York, 109-110. 807p.
- Caton, L.W. 1991. Improved Subsampling Methods for the EPA "Rapid Bioassessment" Benthic Protocols. Bulletin of the North American Benthological Society 8(3): 317-319.
- Columbus State University. 2000. Quality Assurance Project Plan (QAPP): Ecoregions Reference Site Project for Wadeable Streams in Georgia. Prepared for: Georgia Environmental Protection Division (GAEPD) and U. S. Environmental Protection Agency (USEPA).
- Ferring, T. 2005. Analysis of QA/QC Protocols and Value of Data to the Development of Reference Criteria in the Georgia Ecoregions Project. Masters Thesis. Columbus State University. Columbus, GA.
- Georgia Bioassessment Protocol. [Draft] Georgia Department of Natural Resources.
- Gore, J. A., J. R. Olson, D. L. Hughes, P. M. Brossett. 2004. Reference Conditions for Wadeable Streams in Georgia with a Multimetric Index for the Bioassessment and Discrimination of Reference and Impaired Streams. Columbus State University. 363p.
- Hilsenhoff, W. L. 1987. An Improved Biotic Index of Organic Stream Pollution. The Great Lakes Entomologist. 20. 31-39.

- Griffith, G. E., J. M. Omernik, J. A. Cornstock, S. Lawrence, and T. Foster. 2001. Level III and IV Ecoregions of Georgia [ecoregional boundary data sets in a polygonal vector format as ArcInfo export coverage on the Internet]. Revision 5. Corvallis OR: US EPA, National Health and Environmental Effects Research Lab/ORD, Western Ecology Division. Can be obtained from Georgia Department of Natural Resources.
- Jessup, B. and J. Gerritsen. Tetra Tech, Inc. 2000. Development of a Multimetric Index for Biological Assessment of Idaho Streams using Benthic Macroinvertebrates. Idaho Department of Environmental Quality.
- Karr, J. R. and E. W. Chu. 1999. Restoring Life in Running Waters: Better Biological Monitoring. Island Press: Washington D.C. 206. (168-170).
- Karr, J. R. 1991. Biological integrity: A Long-neglected Aspect of Water Resource Management. *Ecological Applications* 1: 66-84.
- Karr, J. R. 1981. Assessment of Biotic Integrity using Fish Communities. *Fisheries* 6: 21-27.
- Merritt, R. W., K. W. Cummins, and V. H. Resh. 1996. Design of Aquatic Insect Studies: Collecting, Sampling, and Rearing Procedures. An Introduction to the Aquatic Insects of North America. 3rd ed. 862: 12-28.
- Mississippi Department of Environmental Quality (MDEQ). 2003. Development and application of the Mississippi benthic index of stream quality (M-BISQ). Mississippi Department of Environmental Quality, Office of Pollution Control, Jackson, Mississippi (for further information, contact Mr. Randy Reed [601-961-5158]).
- Murtaugh, P. A. 1996. The Statistical Evaluation of Ecological Indicators. *Ecological Applications* 6 (1): 132-139.
- Omernik, J. M. 1987. Map Supplement: Ecoregions of the Conterminous United States. *Annals of the Association of American Geographers* 77: 118-125.
- Paul, M.J. and J. Gerritsen. (Tetra Tech, Inc) 2002. Draft Statistical Guidance for Developing Indicators for Rivers and Streams: A Guide for Constructing Multimetric and Multivariate Predictive Bioassessment Models. EPA Office of Research and Development.

- Rankin, E.T. 1989. The Qualitative Habitat Evaluation Index (QHEI): Rational, Methods, and Application. State of Ohio Environmental Protection Agency. Ecological Assessment Section. Division of Water Quality, Planning, and Assessment.
- Rankin, E. T. 1995. Habitat Indices in Water Resource Quality Assessment. Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Ed. Davis, W. S. and T. P. Simon. Lewis Publishers: New York. 415. (181-208).
- Ricker, W. E. 1934. An Ecological Classification of Certain Ontario Streams. The University of Toronto Press. Publications of the Ontario Fisheries Research Laboratory. No 49. University of Toronto Studies, Biological Series No 37. 114 pages.
- Resh, V.H. 1995. Freshwater Benthic Macroinvertebrates and Rapid Assessment Procedures for Water Quality Monitoring in Developing and Newly Industrialized Countries. Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Ed. Davis, W. S. and T. P. Simon. Lewis Publishers: New York. 415. (167-177).
- Statsoft Inc. 2000. Statistica. Version 6.1. Computer Software. Tulsa, OK.
- Tetra Tech, Inc. 2001. Ecological Data Application System (EDAS). Version 3.3.2k. Computer Software. Owings Mills, MD (for further information, contact Mr. Erik Leppo [410-356-8993]).
- Tetra Tech, Inc. 2001. Watershed Characterization Report. Rockdale County Report.
- Vermont Department of Environmental Conservation. Feb 2004. Biocriteria for Fish and Macroinvertebrate Assemblages in Vermont Wadeable Streams and Rivers: Development Phase. Water Quality Division. Biomonitoring and Aquatic Studies Session.
- Williams, J.A. 2004. A Cost Effective Approach to Taxonomic Resolution for Bioassessment and Monitoring Programs in the State of Georgia. Masters Thesis. Columbus State University, Columbus, Georgia.

